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Helical Screw Expander Evaluation Project

Final Report

Richard McKay

March 1, 1982

Prepared for
U.S. Department of Energy
Through an Agreement with
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ABSTRACT

The objectives of the Helical Screw Expander Evaluation Project were to evaluate and characterize a 1-MW helical rotary screw expander power system for electric power generation from geothermal brine. The technology explored in the testing is simple, potentially very efficient, and ideally suited to wellhead installations in moderate to high enthalpy, liquid-dominated fields. A functional 1-MW geothermal electric power plant that featured a helical screw expander was produced and then tested in Utah in 1978-79 with a demonstrated average performance of approximately 45% machine efficiency over a wide range of test conditions in noncondensing operation on two-phase geothermal fluids. The Project also produced a computer-equipped data system, an instrumentation and control van, and a 1000-kW variable load bank, all integrated into a test array designed for operation at a variety of remote test sites.

The test data are known to be valid but they characterize an expander having large internal clearances or leakage passages past the rotors which, contrary to plan, did not close with scale deposits during the testing. Analysis of the data showed that the expander efficiency is a strong function of load, a weak function of inlet steam quality and of pressure ratio across the expander, and independent of throttle position. The efficiency is fairly flat above one-quarter load. Test conditions included inlet pressure ranging from 84 to 258 psia, inlet steam quality of 0 to 99%, linear throttle position from 7 to 100% open, output shaft load of 0 to 1059 kW, with output shaft or male rotor speed of 3000 rpm. The exhaust pressure was atmospheric at about 12 psia except for a few tests performed at exhaust pressures of 27 to 30 psia.

Additional testing was performed in Mexico in 1980 under a cooperative test program using the same test array, and machine efficiency was measured at 62% maximum with the rotors partially coated with scale, compared with approximately 54% maximum in Utah with uncoated rotors, confirming the importance of scale deposits within the machine on performance.

Data are presented in this report for the Utah testing and for the noncondensing phases of the testing in Mexico. Test time loggeo was 437 hours during the Utah tests and 1101 hours during the Mexico tests. Ultimate performance data for the helical screw expander must await the testing of this or another machine with the internal clearances substantially reduced.

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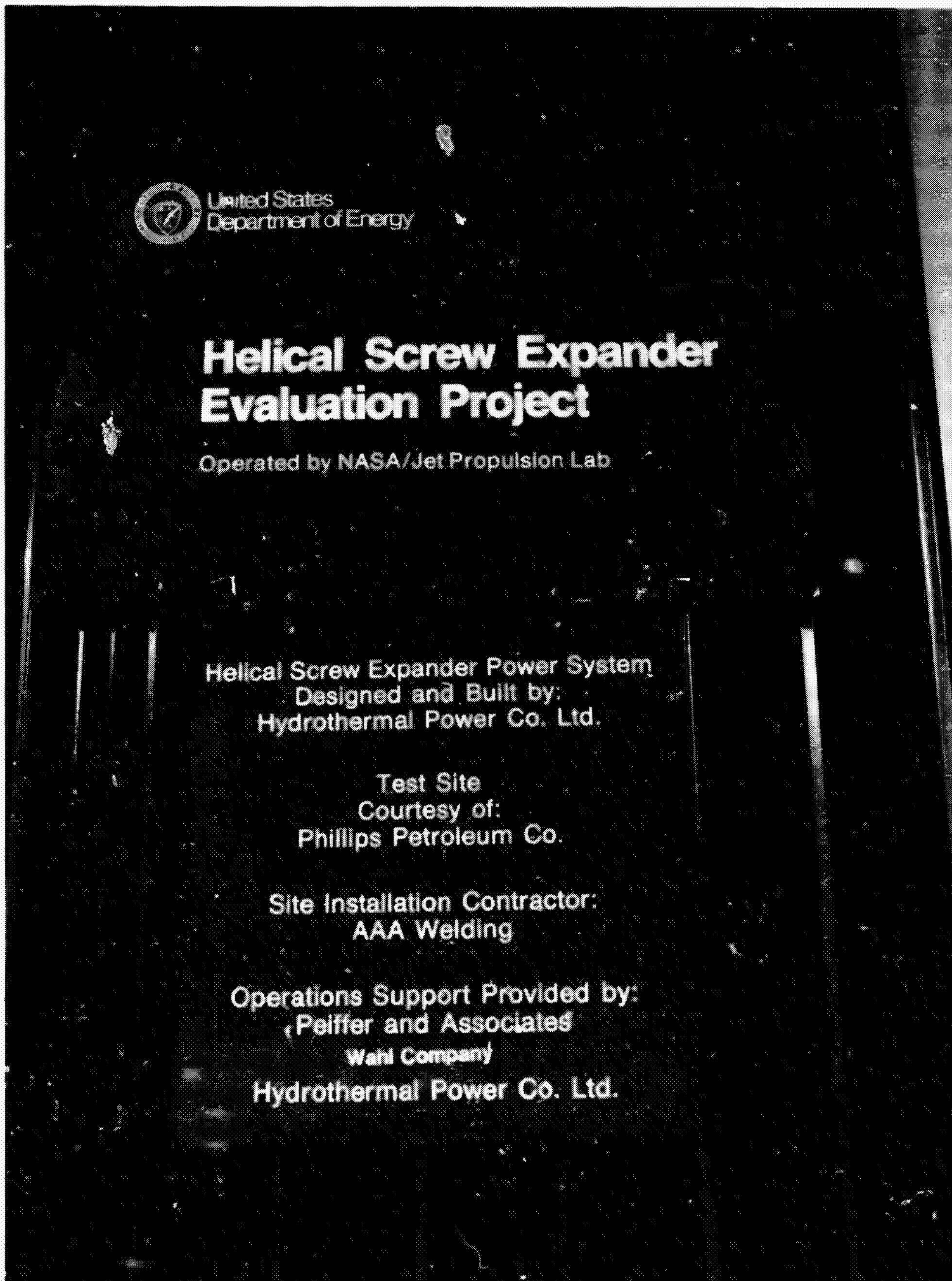

ACKNOWLEDGMENTS

This Project was based on the prior work and continuing participation of Roger S. Sprankle and Hydrothermal Power Company, Ltd., without which there would have been no Helical Screw Expander Evaluation Project. Under contract to JPL, HPC designed and manufactured the HSE power plant and assisted throughout all phases of the Project.

The original Project proposal was prepared by the author of this report in response to the NSF-RANN objectives annuciated by Ritchie Coryell at NSF, who guided the proposal through peer review and National Science Board review with the assistance of Ken Brunot, also at NSF. At JPL, Dr. Marshall E. Alper and Yukio Nakamura played key roles in the formation and initiation of the Project by providing guidance and support. The constructive participation of Mr. Nakamura continued throughout the duration of the Project, unofficially as advisor or officially at other times as JPL Program Manager.

The Project was supported approximately equally by NSF and DOE/ERDA funds which were administered through the NASA Energy Systems Division, Office of Energy Programs. Notable program management was provided at various times by Ronald S. H. Toms, Clifton B. McFarland and Raymond LaSala at DOE/ERDA and by Daniel J. Kerrisk at JPL.

At JPL, Maynard A. Thompson provided outstanding support beginning with the early planning in 1973 and continuing with specialized electrical engineering and general project support until his untimely death in the spring of 1978. He performed the conceptual design and procurement of the load bank and the instrument trailer for JPL, and provided review and guidance for some of the HPC procurements for the power plant. Mr. Thompson and this Project were ably assisted by Ralph Smith, whose many contributions included the preparation of the drawings for the test support power equipment supplied by JPL, the preparation of the manual for the JPL Test Support Equipment (Ref. 2) and relevant consultations, especially during 1978 and 1979.

Also at JPL, Walter S. West designed and documented the data system, procured the components, supervised or performed their installation, wrote the initial part of the computer program, installed and calibrated the process instruments in Utah in 1978, participated in putting the system into initial operation for the testing there and consulted on the subsequent system use and document supplementation. Much of the success of the data acquisition is credited to his work.

Dr. Edward F. Wahl, first from Occidental Research Corporation and then from Wahl Company, reviewed the JPL test process plans and supplied process engineering design support and cost estimates. He wrote and developed computer programs for the testing, for instrument calibration and for data reduction and data analysis, and documented fifteen of the most useful programs in a software manual (Ref. 4). He performed the major part of the data analysis presented in this report, including the data correlation. He also did data system trouble-shooting and repair in 1979 and assisted with some of the field testinq. His high level of interest and his imaginative programming are especially acknowledged.

Phillips Petroleum Company donated the use of its geothermal test facility at Roosevelt Hot Springs, Utah, largely because of the interested support of Dr. Charles W. Berge, Manager of Geothermal Operations, and Don C. Harban, Project Engineer of that organization. The importance of their contributions cannot be overemphasized. Mr. Harban was instrumental in arranging for Phillips to supply piping drawings and hardware at cost.

The process piping was installed by AAA Welding, Inc., under the co-supervision of O'Dell Webb, President, and Lee Peiffer of Peiffer and Associates. Special credit belongs to all who endured the cold and the long hours at the test site in the winter in order to complete the installation on a tight schedule. The experience, leadership and enthusiastic support contributed by Lee Peiffer throughout the 1978 field activities are particularly noteworthy. The important participation of AAA Welding, Inc. extended through the testing and equipment packing in 1979 and the site clean-up.

Halliburton Corporation donated the use of a 500-bbl tank throughout the 1979 testing.

This study was sponsored by the U.S. Department of Energy, Division of Geothermal Energy, under Interagency Agreement No. DE-AI01-76ET28329, amended, with the National Aeronautics and Space Administration under NASA Contract NAS7-100, Task Order No. RD-176.

CONTENTS

SECTION I

INTRODUCTION AND SUMMARY

A. INTRODUCTION

This document is the Final Report of a project sponsored by the United States Government to evaluate and characterize a 1-MW helical rotary screw expander power system for electrical power generation from geothermal brine (Figure 1-1). This report was prepared and submitted by the Jet Propulsion Laboratory (JPL) in compliance with the Interagency Agreement No. DF-AI01-76ET28329, amended, (formerly Interagency Agreement No. EX-76-I-01-1000) between the United States Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA) as implemented by JPL under NASA Task Order RD-176, NAS7-100.

Prior to this Project, the helical screw expander (HSE) power system had undergone development by Hydrothermal Power Co., Ltd. (HPC) and Roger S. Sprankle (Sprankle) who conceived the idea of adapting a Lysholm-type machine to wellhead service on two-phase fluids as a means of exploiting liquid-dominated geothermal energy resources. The development work was done with a 50-kW prototype system; the prototype power plant is shown in Figure 1-2. The main purpose of this Project was to obtain credible data to enable industry to make its own determination as to the commercial suitability of the HSE power system for geothermal utilization in the machine's present state of development. The 1-MW HSE power system used in the evaluation was procured from HPC, and HPC operated the power system under contract to JPL during the evaluation testing in 1978 and 1979. The testing was limited to noncondensing operation at 3000 rpm using fluid from Well 54-3 in the Roosevelt Known Geothermal Resource Area (KGRA), Utah, through the courtesy of Phillips Petroleum Company (Phillips).

The test results must be considered as preliminary because the production of final dimensions within the test HSE requires the deposition of scale internally in amounts which did not occur during the tests. Therefore, a definitive performance evaluation of the HSE and the power system was not possible. However, the Helical Screw Expander Evaluation Project has produced a functional 1-MW geothermal electric power plant featuring a helical screw expander with a demonstrated performance of better than 50% machine efficiency over a range of test conditions in noncondensing operation on two-phase geothermal fluids, a computer-equipped data system, an instrumentation and control data van, and a 1000-kW variable load bank, all integrated into a test array designed for operation at a variety of remote test sites. The Project has also produced an operating and maintenance manual for the power plant (Ref. 1), a manual for the test support equipment (Ref. 2), a data system hardware and calculation manual (Ref. 3), a complete computer program manual for logging, displaying and

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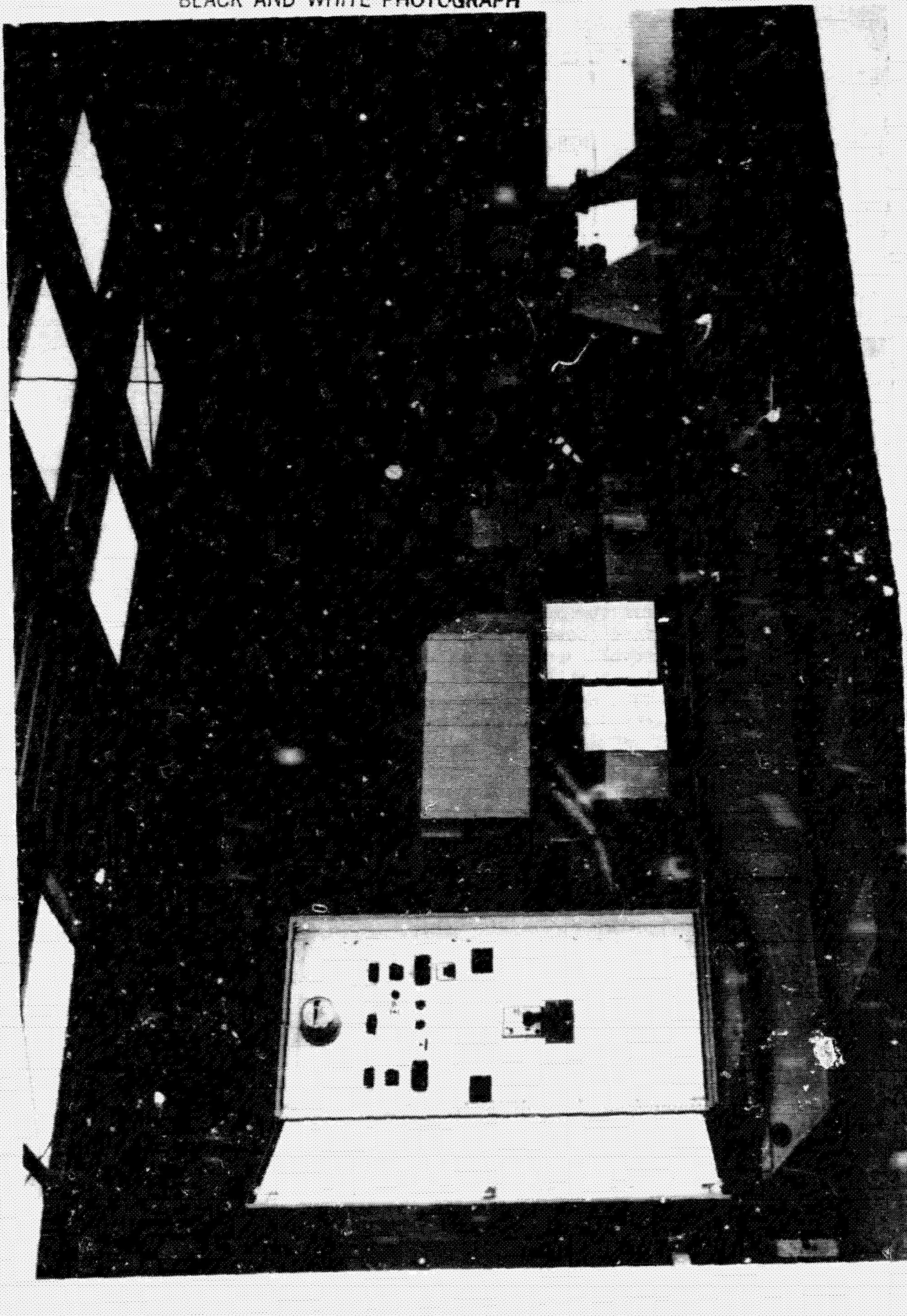

Figure 1-1. 1-MW Helical Screw Expander Power System
(Courtesy of U.S. Department of Energy)

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Figure 1-2. 50-kW (62.5 kVA) Prototype Helical Screw Expander Power System

Note: HSE power system complete with expander, gear box, electric generator, forced lubrication system, governor, instrumentation, resistance load cells, and floodlights. Inventor Roger S. Sprankle and JPL's Yukio Nakamura discuss the system.

analyzing test data (Ref. 4), 151 sets[1] of field test performance data selected under steady-state conditions, and information on the operating characteristics of the HSE over a broad range of operating conditions presented in this Project Final Report. In addition, this Project has provided added experience for technical specialists from JPL and from HPC. It has inspired the continued participation of the DOE Division of Geothermal Energy (DOE/DGE) and the two technical specialists in a cooperative International Test and Demonstration Programme (Programme) requested by the national electric utilities of Mexico, Italy and New Zealand. A test program has already been conducted in Mexico, and similar test programs will be conducted in Italy and then in New Zealand, under the auspices of the International Energy Agency (IEA).

The preparation of this Project Final Report presenting the results of the testing in Utah was rescheduled to begin after the testing in Mexico became routine so that it would not delay the testing. This has led to the opportunity to include in this report an additional 62 sets of data for the noncondensing testing of the HSE performed in Mexico in 1980. These data include a peak measured machine efficiency of 62% with the rotors partially coated with scale, confirming the importance of scale deposits within the machine on machine performance. The testing in Mexico by the Comision Federal de Electricidad (CFE) using the test array from Utah, the gathering of data in a format compatible with the prior work, and the JPL analysis and presentation of these data here in the format developed for the Utah data, all help to demonstrate the suitability and versatility of the equipment and methodologies developed for this Project. It also served as an example which can be followed throughout the Programme. Data for preliminary condensing testing performed in Mexico in 1981 are not presented in this report, nor is a discussion of the 1980 testing included. A summary report by JPL, based on reports by each of the countries, has been scheduled following the completion of the Programme. The participation of JPL in this cooperative Programme is by Interagency Agreement No. DE-AI03-79ET37116 between DOE and NASA under NASA Task Order RD-152, Amendment 226, NAS7-100.

B. SUMMARY

The HSE Project is important because it deals with a geothermal utilization technology which is simple, potentially very efficient, and ideally suited to wellhead installations in moderate to high enthalpy liquid-dominated fields. The general objective of the Project was to provide credible information so that the geothermal community can make its own assessment of the commercial suitability of this technology.

[1] One set consists of the averages of a group of complete data samples; a typical group contains approximately 15 samples of 43 data channels.

The primary technical objective of the Project was to determine the performance of the HSE, in the field, over a wide range of operating conditions simulating a variety of geothermal wells. The main purpose of the field tests was to determine engine efficiency, operating characteristics and equipment durability for noncondensing operations.

This Project was formulated by JPL in close association with Sprankle for the program objectives of National Science Foundation (NSF). A primary NSF program objective was the acceleration of geothermal energy utilization for electric power production from liquid-dominated resources. This appeared possible by drawing on the background technology of Sprankle and HPC. Government sponsorship passed from the NSF to the Energy Research and Development Administration (ERDA) to DOE/DGE.

Several organizations participated in this Project. Most notable were HPC, JPL, Phillips, AAA Welding, Inc., Peiffer and Associates, and Wahl Co. HPC fabricated, installed, operated and maintained the HSE power plant and assisted in the test site selection, test planning and testing, all under JPL contract and direction. JPL managed this Project, designed and fabricated, or assembled, the test support equipment, selected a test site, designed a test process and plan, directed and monitored the field installation, conducted the testing, and participated in the data analysis. Phillips donated the use of its geothermal flow test facility (FTF) at Roosevelt Hot Springs, Utah, and supplied the piping drawings and hardware at cost. AAA Welding, Inc. installed the piping under the co-supervision of consultant Lee Peiffer of Peiffer and Associates and JPL. Dr. E. F. Wahl of Wahl Co. wrote the computer programs for instrument calibration, test operation and data analysis. He also did data system trouble-shooting and repair in 1979, and performed much of the data analysis. Earlier, with associates at Occidental Research Co., Dr. Wahl supplied process engineering support and cost estimates.

As part of the Project proposal marketing, JPL participated with HPC in the demonstration testing of the HPC 50-kW HSE prototype power system, at two sites in the Imperial Valley of California, in 1974. This project to evaluate the 1-MW HSE power system, or power plant, began in September 1975.

Fabrication of the 1-MW HSE power plant, Model 76-1, by HPC, began in March 1976 after a period of design and design review, fabrication shop preparation, component procurement actions and approvals, and the establishment of quality control and other procedures required by JPL. The fabrication was completed in August 1977, and the plant was subjected to acceptance testing by HPC and JPL the same month. The testing was done to check the static and dynamic performance of the power plant and its subsystems, and the interfacing with test support equipment provided by JPL. The test support equipment included a computer-based data acquisition system, and a means of remote control and monitoring of the power plant. The test support equipment was designed and built or purchased by JPL during the fabrication of the power plant.

A series of dynamic tests, in August, September and October, accomplished by driving the HSE with compressed air, revealed design weaknesses in the governor drive, the shaft seal assemblies, and the timing gear lubrication in the HSE. After making repairs, acceptance testing was completed December 4, 1977, when the HSE power plant met all the test criteria during 4 hours of continuous operation.

After the in-place delivery of the power plant to JPL, modifications were made to an electrical distribution panel to match the process needs at the Utah test site. The Utah site had been selected after a site survey made by JPL and HPC during the period of equipment fabrication. A test process was designed to use fluids from Phillips' Well 54-3 after the fluids had passed through a separator in the FTF. The main purpose of the FTF during 1978 was the evaluation of the geothermal reservoir, and during 1979 the main purpose was the development of production techniques by Phillips. The pressure and flow rates of the fluids available to this Project were determined by the design and test conditions of the FTF. The design and operation of the HSE test facility was strongly influenced by the FTF design and test conditions. Long piping runs and waste disposal equipment dictated by the FTF required the expenditure of Project funds originally planned for condensing testing.

Site preparation began in December 1977. Piping hardware began to arrive at the site that same month, and the HSE power plant and test support equipment arrived during February 1978. The process piping installation began in January and was completed by the middle of March, at which time all of the equipment was in-place, installed and ready for use. Relatively moderate winter weather at the 6000-foot altitude of the test site, resulting in fewer storms than normal, aided in the preparations.

The 1978 testing was conducted during the period of March 16 through May 30. During this period, testing of the HSE under full power and with scale deposited on the rotors was precluded by the operating conditions of the FTF. Both conditions, full power and scale deposited on the rotors, were necessary for an adequate evaluation of the HSE. However, these initial tests revealed weaknesses in the design of the HSE most notably the shaft seals. The design weaknesses were strengthened, new parts were installed, and operating conditions of the FTF desirable for testing the HSE were planned by Phillips for the 1979 operations. Verification testing of the HSE during the period of October 12, 1979 through November 14, 1979 confirmed the adequacy of the design and installation of the new parts. Unfortunately, a well "blowout" in the FTF occurred during test preparations, the planned operating conditions of the FTF were not achieved, and an adequate evaluation of the HSE was not possible.

In advance of the 1978 testing, the DOE/DGE, guided by its advisory committees, classified this Project as low priority and scheduled it for termination. However, these tests generated considerable interest in Mexico, Italy, New Zealand and other countries, and it was decided that CFE, Mexico, Ente Nazionale per l'Energia Elettrica (ENEL), Italy, and the Ministry of Works and Development

(MWD), New Zealand, would test the machine in each of these three countries under the auspices of the IEA, with the continued participation of DOE/DGE, JPL and HPC. It is for this reason that the overhaul and 1979 testing were performed. In support of the proposed testing by CFE in Mexico, JPL performed an analysis of two proposed test sites at Cerro Prieto, Mexico, and, with HPC, prepared process designs and cost studies for several test options there. This advance planning support was done during the preparation for the 1979 testing in Utah as part of this Project. In November, after the testing in Utah, the HSE power plant and test support equipment were disconnected and loaded for shipment to Mexico, arriving at Cerro Prieto for unloading on December 1, 1979.

The Model 76-1 HSE is a positive displacement Lysholm-type machine adapted from the technology of the compressor industry. It was designed for wellhead operation on brine and steam mixtures which deposit scale. Some scale deposit is desirable, but only in controlled amounts. In order to accommodate and control the expected scale deposits, it was built with rotor-to-rotor and rotor-to-case clearances which would be excessive for conventional application. Earlier field experience with the prototype had shown that scale deposits can close these clearances during operation. Until they close, these clearances allow sufficient leakage to impair the performance significantly. This is illustrated by including in this report the 1980 Mexico test data which show a maximum performance measurement of the machine efficiency of 62% at Cerro Prieto, Mexico, with the rotors partly scale-clad, as compared with a machine efficiency of approximately 54% measured in Utah under similar test conditions, but with the rotors still bare. The efficiency improvement is believed to have resulted from leakage reduction by the scale. Since the fluid properties and test time available in Utah left the rotors nearly bare throughout the testing there, the Utah performance data are quantitatively irrelevant to the HSE evaluation. Unfortunately, the combination of the process configuration and the test time available in Mexico did not permit complete scaling of the rotors there either, and the performance potential was still unknown at the end of the testing in Mexico.

The Utah test conditions included an inlet pressure to the expander of 84 psia to 258 psia, inlet steam quality of 0 to 99%, electric load of 62 to 1002 kW, shaft output power of 101 to 1059 kW, and a male rotor speed of 3000 rpm. The expander exhaust pressure was mostly atmospheric at about 12 psia. Some testing was performed at exhaust pressures of 27 to 30 psia. When it was found during the 1979 testing that process conditions planned for scale deposition within the expander were not available from the FTF, attempts were made to deposit calcium carbonate on the rotors by injecting calcium chloride solution into the inlet of the expander as an aid to the performance evaluation. The results showed little success, possibly because of the presence of scale inhibitor injected into the fluids at the wellhead by Phillips during much of the testing. Enough scale was deposited on the rotors to confirm that the machine efficiency increases with a decrease in the leakage clearances. The 1979 testing also confirmed that the design improvements in shaft seals, throttle control, fluid entry control and noise level were all successful.

The 1978 and 1979 testing was for noncondensing operation at a male rotor and output shaft speed of 3000 rpm, with essentially bare rotors. An analysis of the test data shows that the machine efficiency of the HSE is a strong function of shaft output power, and a weak function of inlet steam quality and pressure ratio across the expander. The efficiency is independent of throttle position and fluid throughput. These test results, in conjunction with the 1980 Mexico data for the same rotor speed, show conclusively that testing of the HSE under scale-forming conditions, with the rotors and case interior coated to the limiting dimensions, is necessary to determine the efficiency and performance characteristics of the HSE. Under those conditions, the optimum speed of the rotors and the effects of condensing operation should be determined, along with the durability of the components. The test results here should be considered as encouraging and appear to justify additional testing of the HSE.

C. BACKGROUND

This Project was based on the prior work of Sprankle and HPC during the period 1971 through 1973 and on the geothermal program objectives of NSF in the period immediately following. The idea of applying a Lysholm-type positive displacement machine to two-phase flow geothermal service was conceived by Sprankle in January 1971, and was confirmed during approximately 400 hours of testing of a 4-inch rotor machine on Well M-10 at Cerro Prieto, Mexico, during October of that year. The test results were submitted to CFE in an unpublished paper, and the new concept was promoted by HPC in a bulletin distributed at the first Geothermal Resources Council Symposium in Brawley, California, in February 1972. Sprankle filed for a use patent with the United States Patent Office and formed HPC, with himself as general partner, to exploit the concept. Patent No. 3,751,673 was granted to Roger S. Sprankle on August 7, 1973 and subsequently was signed over to HPC.

During 1972, HPC developed and tested a 50-kW prototype HSE power plant by adapting a Gardner-Denver compressor with 6-inch rotors. The testing and much of the development work were done at Well M-7, Cerro Prieto, Mexico (see Figure 1-2). As with the prior testing, the HSE demonstrated the ability to operate on the two-phase flow of untreated geothermal fluid directly from the well. Scale deposition occurred within the machine in amounts limited by the abrading action of the rotors on one another and on the housing. The scale deposits provided corrosion protection for otherwise exposed surfaces and improved the machine efficiency by reducing leakage past the rotors. Although successful, the prototype expander was not a true geothermal machine, only an adapted compressor, and was not suitable for endurance testing or intensive performance evaluation. However, it did serve as the basis for the conceptual design completed by HPC for a small commercial-size HSE geothermal power plant.

In 1973, the Office of Management and Budget assigned to NSF the role of lead government agency dealing with geothermal energy. In addition to coordinating the relevant work of all other government agencies, NSF included a geothermal program in the Research Applied to National Needs (RANN) directorate.

JPL became aware that this program included accelerating of the production of electricity from hot geothermal brines containing minerals which impeded the development of utilization technology. Accordingly, JPL made a comprehensive survey of the utilization technology as it existed in the fall of 1973, and concluded that the HPC technology was a likely candidate for acceleration. The concept had been verified with good results, and the prime mover which was embodied in the technology was a derivative of compressors built by an established industry. No technological breakthrough was necessary. Moreover, in the context of RANN and the NSF-assigned role in geothermal advancement, the liaison of NSF as a funding agency and JPL as an organization with expertise in project management, to utilize technology in need of further development, with HPC as a small commercially-oriented originator of the technology, was attractive to NSF. It was readily recognized that this liaison could provide the structure for a project to produce and test a small commercial geothermal power plant and to provide the credible data necessary for industry to make its own determination as to the applicability of this technology.

The participation of HPC in an evaluation project sponsored by the United States Government was conditioned upon retention of its then existing patent rights. In addition, as a contractor with JPL, HPC applied for and was granted an advance waiver of the Government's rights with respect to inventions made in the performance of the contract with JPL. The JPL contract with HPC limited this project to the function of evaluation only, while the responsibility for design and further development of the HSE remained with HPC outside of this Project. Neither the Government nor JPL undertook to examine the HPC expander design in detail or to do any design optimization. These areas were left to HPC's initiative.

In support of this Project, proposed to NSF in five phases, the 50-kW prototype HPC power plant was tested at two sites in the Imperial Valley of California. The first site was at the United States Bureau of Reclamation Geothermal Test Facility in the East Mesa KGRA. Performance tests were performed there on August 21, 1974, on low-saline brine from Well 6-1. The test was a cooperative effort with the test crew made up of representatives from the Public Services Department of the City of Burbank, California, the Energy and Minerals Division of Gulf Oil Company, HPC and JPL. The tests gave expander efficiencies of 65 and 74% for two operating conditions. These results were considered tentative since power losses of the load train on the power plant were not accurately known and these losses entered into the calculation of the expander efficiency. No effort was made to optimize the test conditions, and it was known that as an adapted compressor the expander did not represent an optimum design. During May 1975 the machine was tested by HPC and JPL on Phillips' Well, Sinclair 4, where the hot hyper-saline brine contained about 30% dissolved minerals by weight. The expander reached steady state in about 24 hours of operation with no significant problems. These two tests were interpreted as verification of proof of concept of the HSE as a brine tolerant expander for extracting energy from geothermal brine and steam mixtures.

In December 1974 the National Science Board reviewed and approved this Project. The NSF then initiated Project funding procedures through the Energy Systems Division, Office of Energy Programs, NASA, in December 1974. The program and funding authority passed from NSF to ERDA upon its formation in January 1975, and the program responsibility was subsequently merged into the newly formed DOE/DGE in October 1977, when the DGE took over program management of this Project.

D. PROJECT OBJECTIVES

The short-range technical objectives of this Project were to acquire, test, evaluate and characterize a small commercial-size HSE power system for two-phase flow operation in liquid-dominated geothermal fields. The evaluation was to be based on testing in the field to determine the engine and plant efficiencies of the power system, and the effects of operating parameters such as inlet pressure, inlet quality, exhaust pressure and rotor tip speed. Also to be studied were corrosion, scale formation and its effects, rotor and housing wear, erosion, durability, maintenance requirements, throttle behavior, start/stop requirements, parasitic losses, interactions with the well, interactions with an electric grid, and expander staging, size and other practical details of operating such a system. This information was then to be used for application design studies followed by a 5-MW fully-automated demonstration plant.

The nontechnical objectives were to involve HPC in this Project as the designer and supplier of the power plant and as operator of the power plant during the testing. This was intended to encourage the development of the capability and image of the company as the supplier of HSE power plants in the event that a market should develop. Another objective was to involve the site operators in the testing so that the user point-of-view would be well represented.

E. PROJECT PLAN

1. Proposed Plan

The Helical Screw Expander Evaluation Project was shaped according to the program objectives of the Division of Advanced Energy Research and Technology of the NSF and was proposed in five phases, all to be managed by JPL. All five phases were subject to review by the sponsor to allow continuation, redirection or Project termination at logical points.

Phase I entailed the purchase of a 1000-kW modular power plant from HPC with the design based on the 50-kW HPC prototype. This 20-fold scale-up in size was intended to produce a commercial machine small enough to test comprehensively on single geothermal wells but large enough that all of its components and its operating characteristics would be representative of larger machines.

Concurrently with the procurement of the power plant, JPL planned to design and build test support equipment, select two high-enthalpy test sites, one with low-salinity brine and one with high-salinity brine, and formulate the test plans.

Phase II was to consist of the characterization and evaluation testing of the power system module. It was planned to test with low-saline brine first because the operating problems are less severe and the thermodynamic properties of the fluids are better known. It was hoped to simulate a wide variety of wellhead conditions by separating the fluids from the test well into steam and brine and then recombining them in measured proportions as desired and by admixing a recycled stream of cooled brine as appropriate. Also, a site was to be selected for the Phase III testing.

Phase III was to provide long-term operation in the field for endurance testing and equipment life predictions, well dynamics interaction studies, electric grid interfacing studies and a determination of additional developments needed.

Phase IV would have made use of the results of Phases II and III to study the application of the HSE to the geothermal power industry and to assess the feasibility of wellhead siting in particular.

Phase V was planned for the design, construction, testing, and evaluation of a fully-automated HSE power plant. At that time it was envisioned as being sited near the well and having a two-stage expander with a 5 to 7-MW power rating in noncondensing operation.

The work plan schedule for Phases I and II as approved by NSF is shown in Figure 1-3, and for all five phases in Figure 1-4.

2. Project Funding

Phase I, as funded, had no change in its technical content or objectives. The transfer of program responsibility from NSF to ERDA upon its formation in January 1975 caused a start-date schedule slip of approximately 9 months while agency staffing and policy matters were resolved. The Project plan was reviewed in the context of ERDA program objectives and the Phase I plan was approved with minor nontechnical changes. Some scheduling changes were necessary to correct for the actual times required for JPL to contract for HPC to build the HSE power plant, and for HPC to obtain new competitive bids from suppliers according to government procedures. The Phase I plan for ERDA is shown in Figure 1-5. This plan was later revised as shown in Figure 1-6 and was inherited by DOE/DGE.

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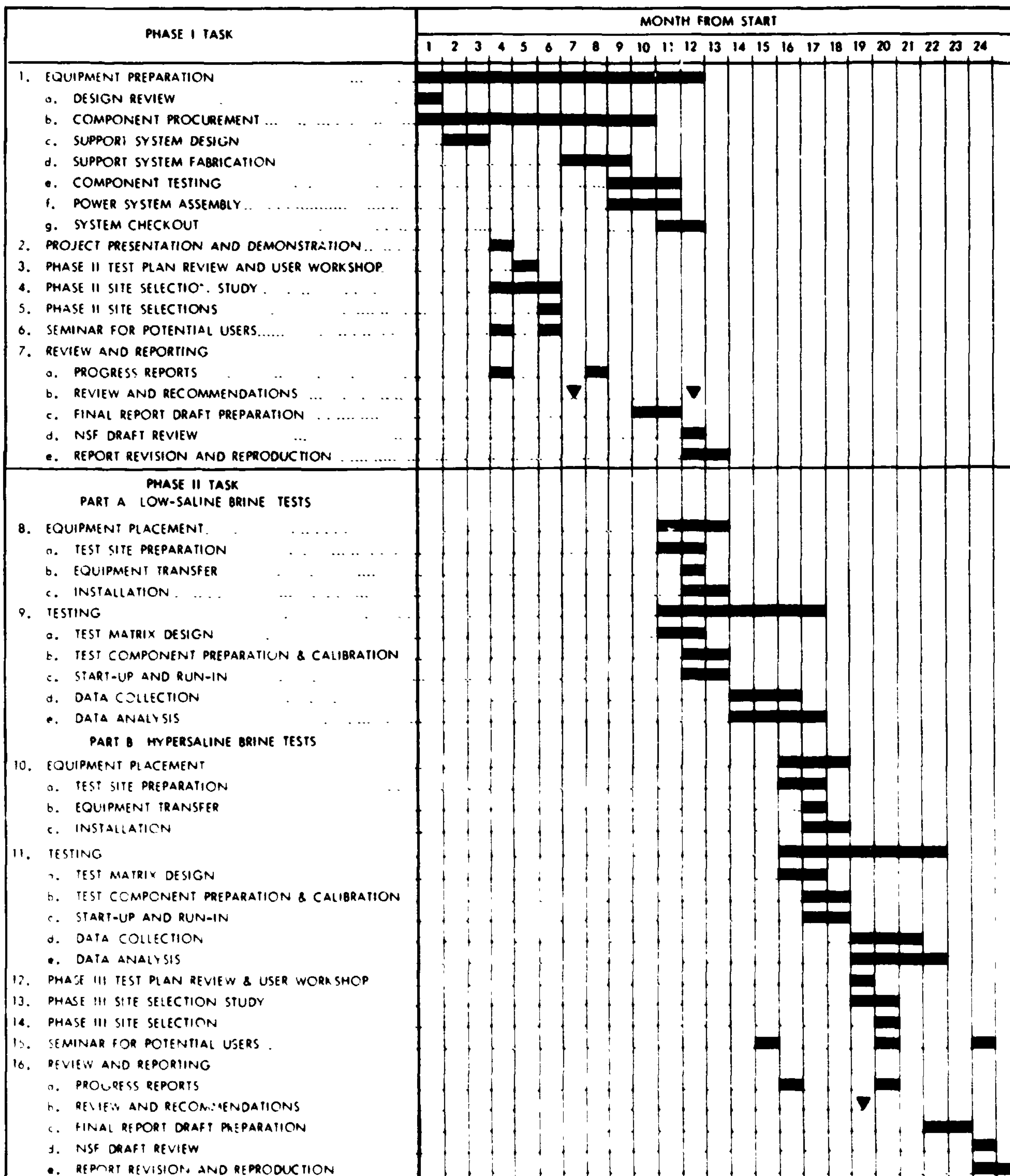

Figure 1-3. Work Plan Schedule, Phase I and II, for NSF

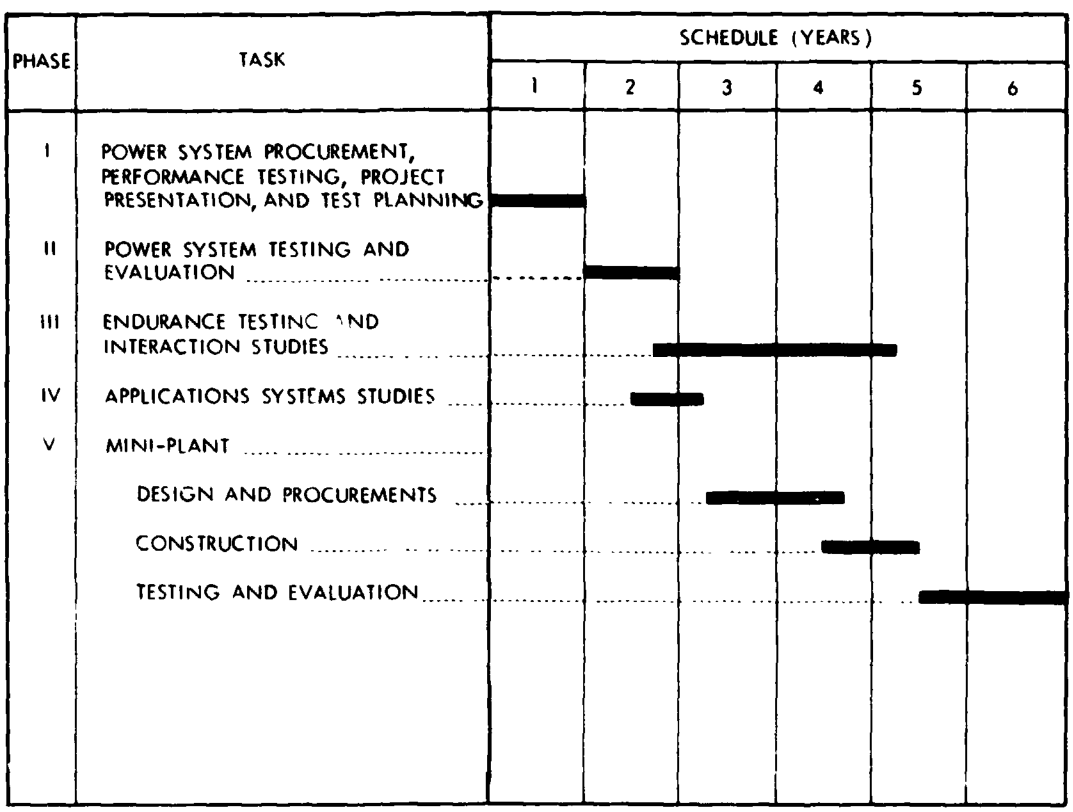

Figure 1-4. Work Plan Schedule, Phases I through V, for NSF

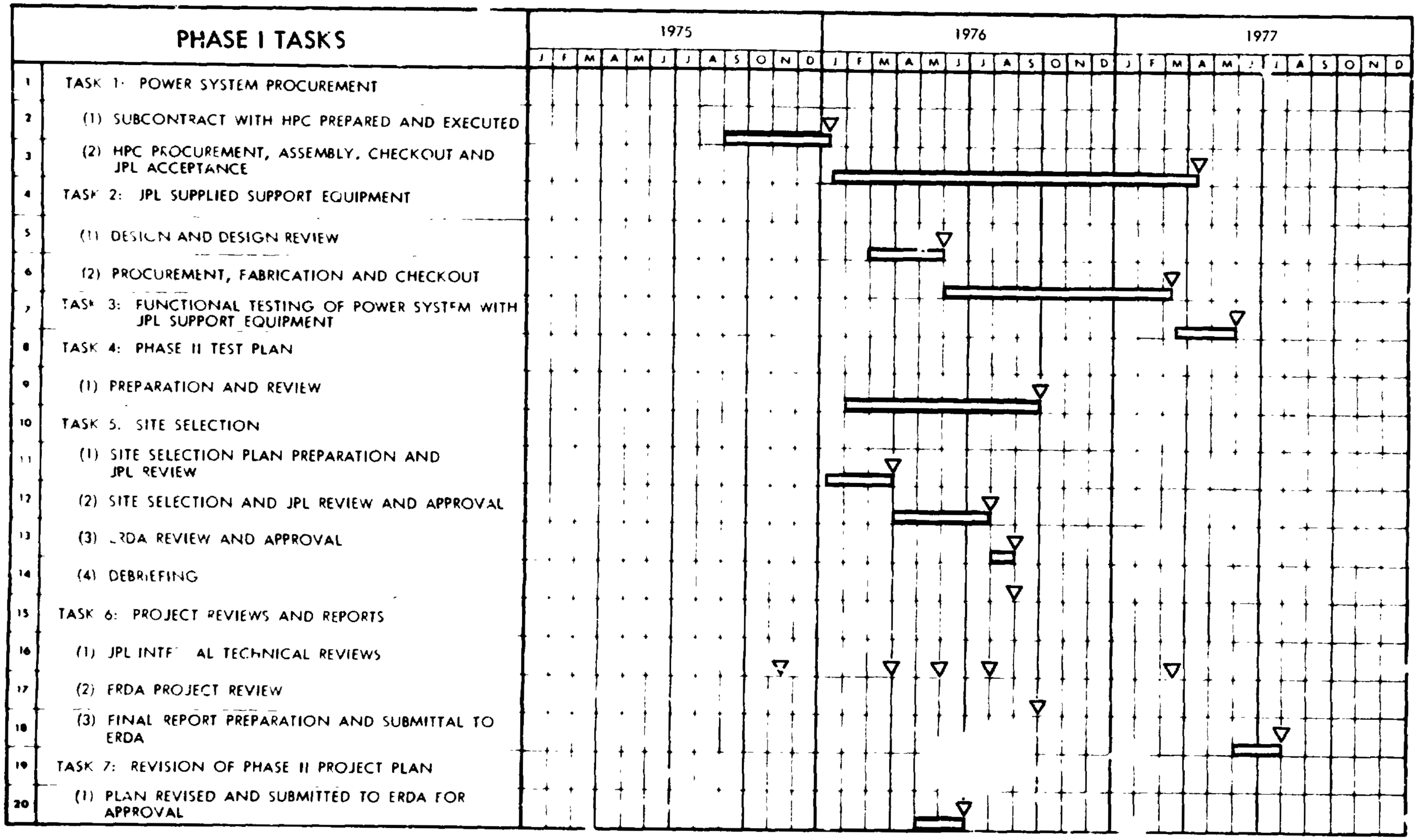

Figure 1-5. Work Plan Schedule, Phase I, for ERDA

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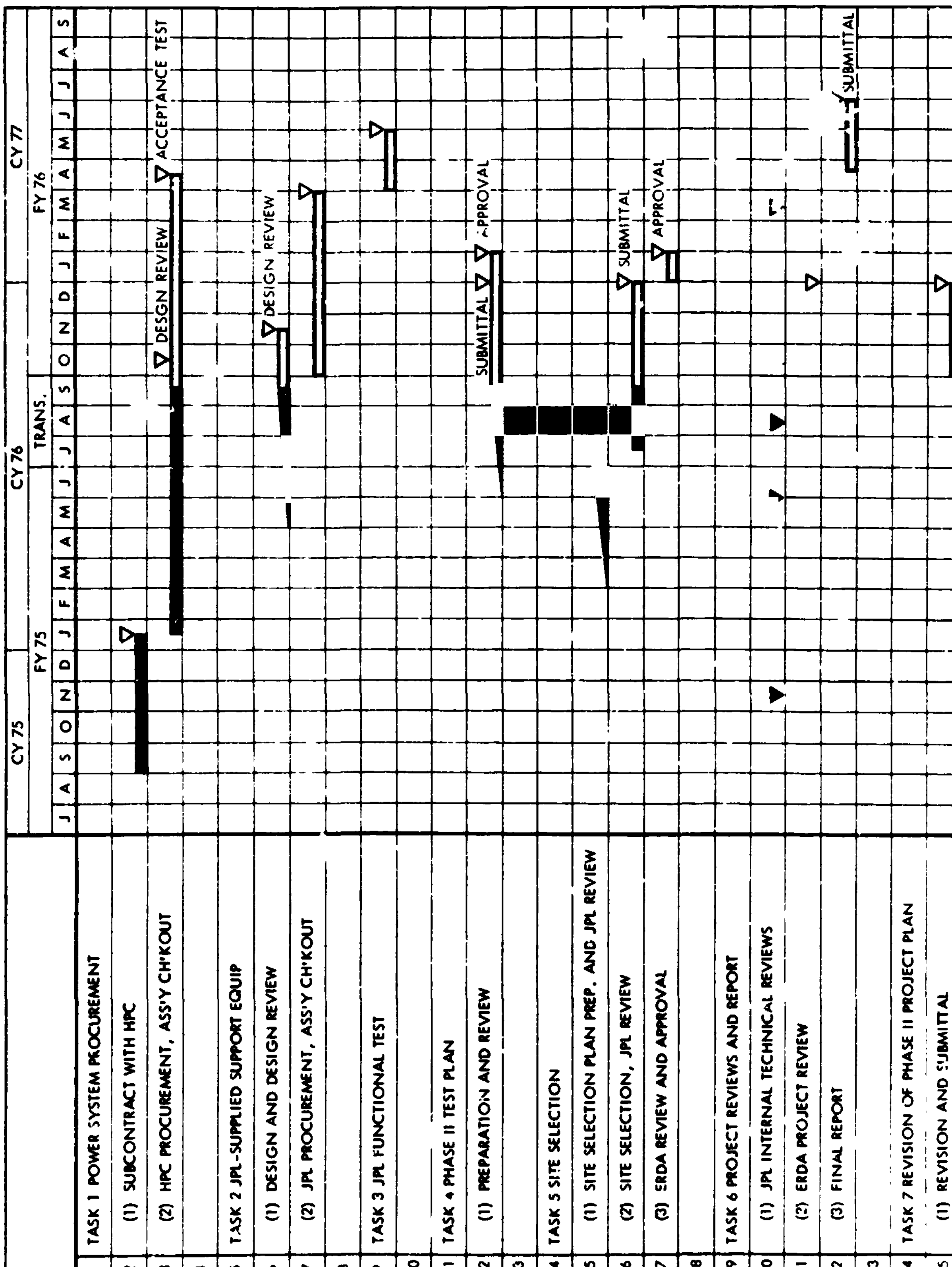


Figure 1-6. Work Plan Schedule, Phase I, for DOE/DGE

Phase II was revised to encompass the testing only at the first test site (Figure 1-7). When testing was about to begin in 1978, JPL learned from DOE/DGE that this Project would be terminated at the completion of the 3 months of testing scheduled in Phase II. In consultation with its advisors, DGE had reviewed all its projects and assigned a priority to each. The HSE geothermal power plant was rated as not of sufficient interest to the geothermal industry in the United States to justify continued Project funding. However, through its membership in the IEA, DOE offered the HSE power plant for testing by other governments, as discussed in Section VIII of this report. As a result, representatives of Italy, New Zealand, Turkey, Sweden and West Germany visited the site during the testing and were encouraged by the test results. At that time, design weaknesses in the shaft seals had become evident and it was clear that some redesign and overhaul would be necessary before testing could continue in another country. Therefore, Phase II was supplemented by Phase II-A to accomplish the appropriate redesign and overhaul and to prepare for an additional month of testing to confirm the adequacy of the overhaul. Meanwhile, the original Phases III, IV and V were cancelled, along with plans for second-site testing in Phase II. Planning support for the Programme was included in the Phase II-A work plan.

Phase III covered the overhaul confirmation testing and was followed by the final phase, Project Termination, proposed separately. In addition to the overhaul confirmation, the 1 month of testing of Phase III was intended to accomplish the performance evaluation of the HSE which had been attempted earlier in Phase II. The efficiency of the HSE is strongly influenced by the leakage clearances past the rotors and these clearances were excessive during the Phase II (1978) testing. Scale deposits had been expected to form within the expander during the testing to close these clearances and bring the machine to its finished dimensions, but this did not occur. Thus, the testing was performed on an unfinished machine and the true performance of the machine was not determined. Process changes were planned for the Phase III testing to allow finished dimensions to be generated. Because the 1978 tests were known to have been performed on an unfinished machine, and the results are not necessarily representative of the HSE, and because the availability of fluids limited the HSE tests to 3/4 power, the reporting of the 1978 test results was rescheduled for inclusion in the Project Final Report, along with the 1979 test results.

The Project Termination activities (equivalent to a Phase IV) included preparing the HSE power plant and test support equipment for shipment from the site, leaving the site in a condition acceptable to Phillips, preparing complete hardware and software documentation to accompany the equipment to foreign test sites, and transferring the accountability of Project property to DOE.

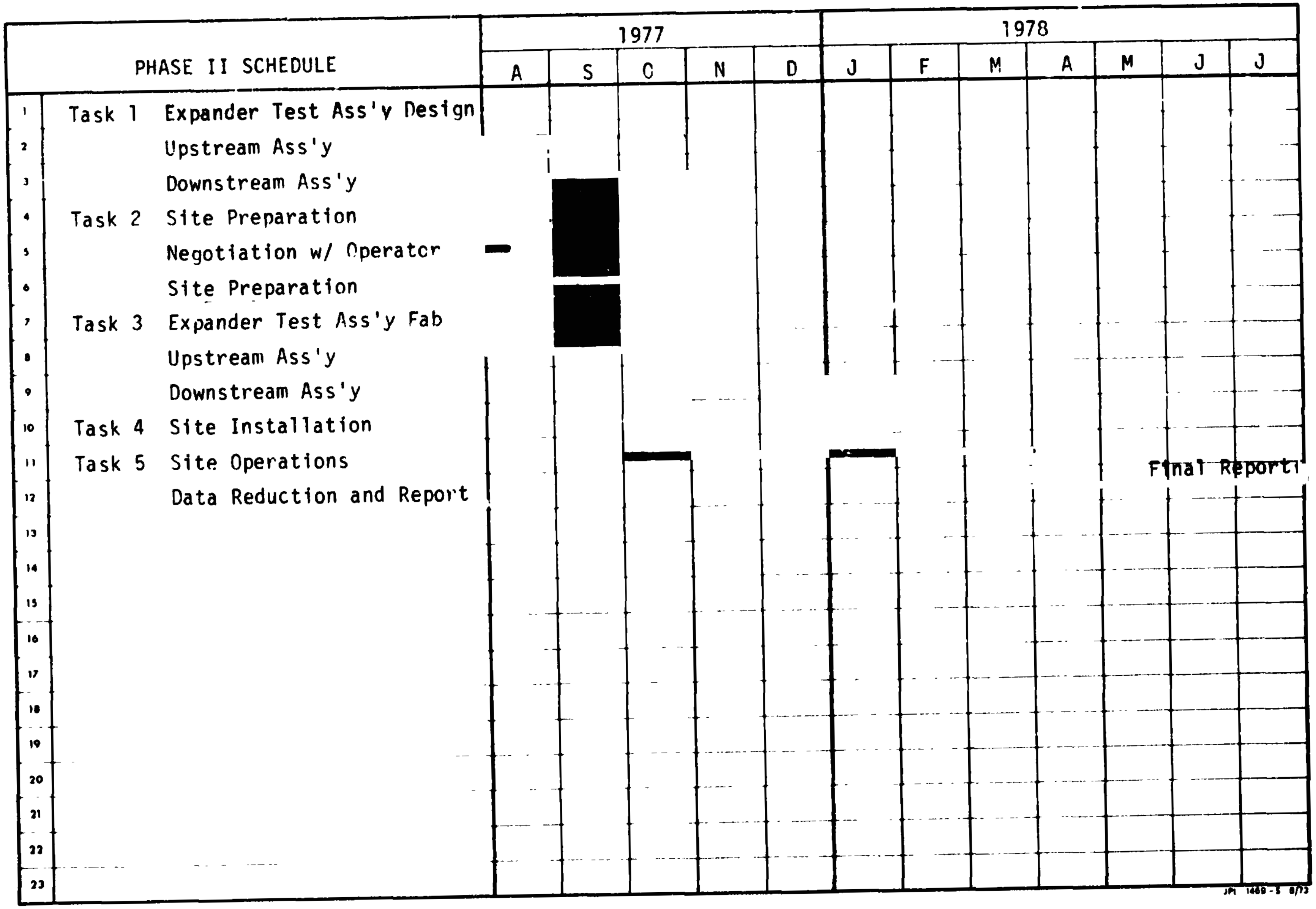


Figure 1-7. Work Plan Schedule, Phase II, for DOE/DGE

SECTION II

METHODOLOGY

A. PROJECT METHODOLOGY

The Helical Screw Expander Evaluation Project methodology encompassed the following main elements: the expander, proprietary considerations, the power plant, the load, data acquisition and management, the test array, the test site and the test process.

The expander is a small commercial geothermal prime mover designed for two-phase fluids by HPC on the basis of prior development work with a prototype machine which was adapted from a Gardner-Denver air compressor. The new machine bears a close resemblance to established machine design because the helical screw rotors were cut by a licensee of Svenska Rotor Maskiner, A.B., Sweden (SRM), to the same profile specifications as those used in compressors. Case design, porting and materials of construction, etc., were all specified by HPC for long-term geothermal service. HPC classified all expander design details as proprietary. This limited the Project to external evaluation of the HSE only, with all design details, repairs, developments and internal measurements being excluded from the Project at the discretion of HPC. The exception was the confidential review by JPL of designs believed to be critical to the expander evaluation objectives of the Project and certain measurements within the expander. This arrangement helped to define the roles of JPL and HPC, and influenced the test planning. Accordingly, complete design details of the HPC expander are not contained in this report. (For a description of the expander see Section II.B.)

The expander was integrated into a power plant so that it could be evaluated in direct relation to its intended application. The power plant served as a test bench for the expander. The expander output was determined by measuring the electrical output of the alternator and correcting for losses in the drive train. High grade commercial components were used throughout, but no attempt was made to specify their performance. For example, for the purposes of this Project, the efficiencies of the gear box and alternator were not important provided they were known, and a component failure external to the expander was not normally considered as relevant to the expander evaluation. Consistent with the overall Project objective of accelerating the commercialization of an energy conversion technology, the power plant was designed as a self-contained, stand-alone unit completely independent of all JPL test equipment. It has its own controls and power instruments, is self-starting on geothermal fluid and has a safety shutdown system to provide protection against faults. The power plant is described in Section II.C.

With the need to load the power plant at test sites expected to be far from load centers, a transportable fan-cooled 1000-kW resistive load bank was provided. Manual switches were used to change the load in 50-kW steps. The load bank was connected to the alternator with power cables of equal length to provide a balanced load on the three phases for accurate power measurement. Details of the load bank are given in Section II.D. and in the support equipment manual (Ref. 2).

An automated data acquisition and display system was designed by JPL to monitor and report, in real time, the status of the test process and some power plant hardware. For this purpose, a desk-top computer received incoming signals originating in the process equipment, or in the power plant, through a multiprogrammer. The calculated status and performance data were displayed on three printers. In this way, process control decisions could be guided, and the results could be clearly observed. A second computer was provided for data analysis, and provision was made for plotting process or equipment parameters on-line or off-line. This equipment, along with signal-conditioning equipment, was installed in an instrumentation and control trailer, or data van, which provided working space and environmental control for the equipment. Compatible in-plant transducers were installed by HPC or its suppliers.

The primary computer monitored the fault status of the power plant. It also recorded the first outage and the status of the process just prior to the fault. Numerous gauges and meters were installed on the power plant and in the process equipment. Some of these were used to confirm information logged automatically. The data system is described in Section II.E. and in more technical detail in a separate data system hardware manual (Ref. 3). The computer software is discussed in Section II.E. and described in a software manual (Ref. 4). The Data Van is described in Section II.F. and in the support equipment manual (Ref. 2). These three manuals, or reference documents, were prepared to describe the test support hardware and software as of the completion of the testing in Utah. The Data Van is equipped for calibrating many of the process transducers on-site. This equipment is listed in the data system hardware manual (Ref. 3).

With the expectation of testing the HSE power plant at more than one site, the power plant, the Data Van and the load bank were integrated into a test array, arranged so that the assembly can be functionally reproduced at all sites. Appropriate junction terminals, mostly on the power plant, were provided for this purpose. The test array lay-out was constrained only by the lengths of the interconnecting cables. Wherever the power plant was installed for testing, its position became established, and the remainder of the test array was positioned accordingly. Wiring from process instruments was connected into the test array at junction terminals on the power plant. The test array is described in Section II.C.

The decision to test the expander on real geothermal fluids in the field not only influenced the design of the hardware but established the need for a test site. Many factors were considered in selecting a site, but the main ones were well production characteristics and availability. A 1-MW power plant undergoing tests to simulate a wide assortment of wells requires a large steam and water flow. The most favorable arrangement is a large well with a high pressure separator. Such an arrangement was available at the Phillips' FTF at Well 54-3 in the Roosevelt KGRA, Utah. Only after this site was selected could the design of the test process proceed. A discussion of test site requirements and the site selection process is presented in Section IV. In advance of the site selection, several processes were designed to establish the flow requirements associated with the desired test conditions. The resulting information, including estimates of associated equipment costs, was used to determine the site requirements and the test possibilities. The availability of large quantities of steam and water from a high pressure separator made it possible to recombine the phases in selected measured amounts, at separator pressure or lower, to simulate a wide variety of wells. A more complete discussion of the test process which was used is found in Section V.A.3.f.

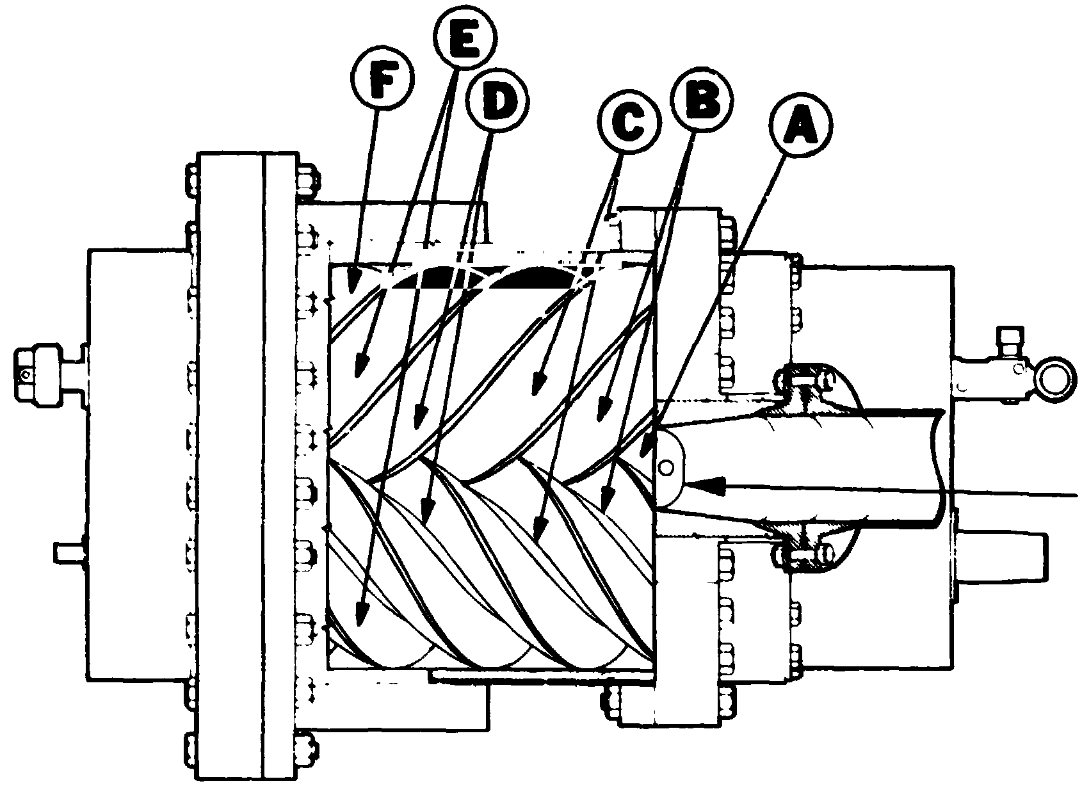
B. EXPANDER

The HSE is a positive displacement machine based on a compressor designed by Alf Lysholm in Sweden in the 1930's, and subsequently developed by SRM. In this Project, the machine is more correctly called an engine than an expander, but it is usually called an expander in industry, and therefore is called an expander in this report.

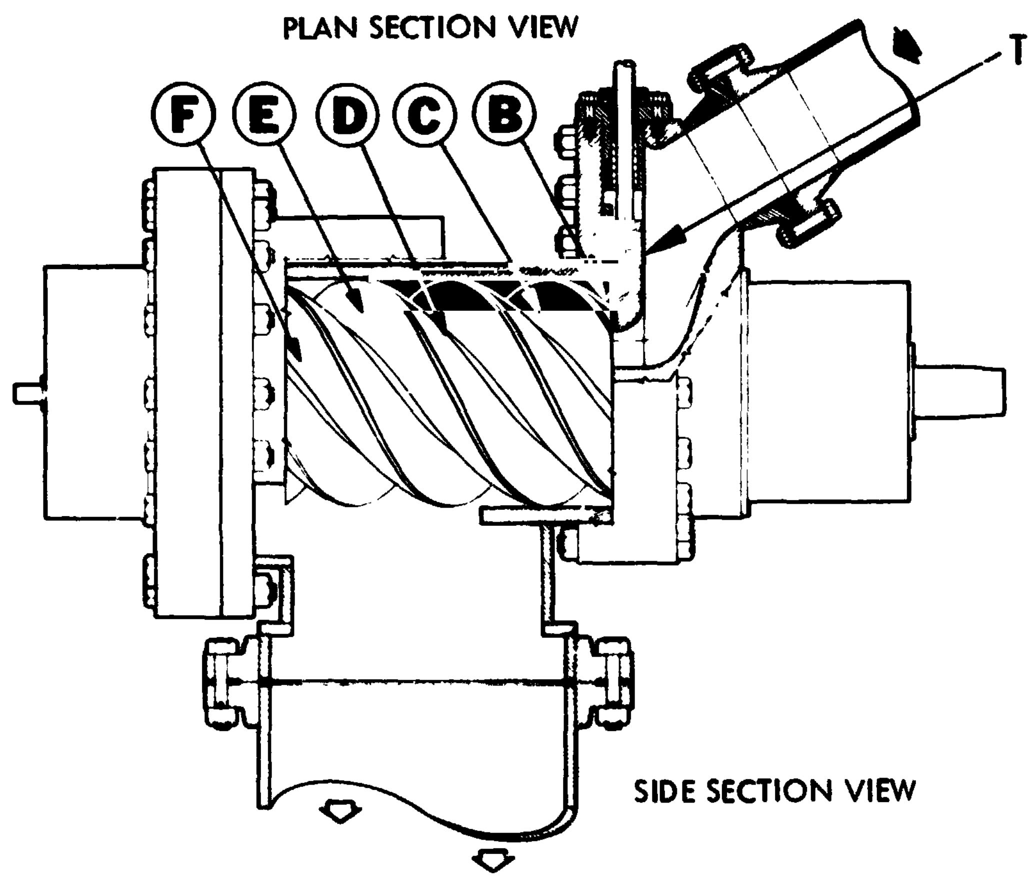
1. Principles of Operation

The expander was designed for wellhead geothermal operation on scaling fluid. The principles of operation are depicted in Figure 2-1. The geothermal fluid, at approximately wellhead pressure, flows to the throttle or flow control valve T, and at high velocity enters the high pressure pocket formed by the meshed rotors, the rotor case bores and the case end face. This pocket, designated by A in the figure, is mostly hidden by the rotor lobes, but can be seen in the plan section view. As the rotors turn, the pocket elongates, splits into a "V" and moves away from the inlet ports to form the regions designated by B. With continued rotation, the "V" lengthens, expanding successively to C, D, E and F, as the point of meshing of the rotors appears to retreat from the expanding fluid. The expanded fluid, at low pressure, is then discharged into the exhaust ports as they are uncovered by the lobes. Within the machine, vapor is continuously being produced from the hot liquid phase as it decreases in pressure during its passage through the expander. The effect is of an infinite series of steam flashers, all within the prime mover. Thus the mass flow of vapor increases continuously as the pressure drops throughout the expansion process, and the total energy stream from the well is carried to the lowest expansion pressure.

Rotor-to-rotor and rotor-to-case clearances, abnormally large for a Lysholm-type machine, were built into the expander to provide space for scale to form within the machine. The scale deposit provides corrosion protection for otherwise exposed surfaces and improves the machine efficiency by reducing leakage clearances past the rotors. The scale cladding may also provide erosion protection in high velocity entry impingement zones, but this hypothesis has not been verified. The rotors are provided with hard tips on the rotor lobes and end faces to limit the build-up of scale in the expander within regions swept by the



PLAN SECTION VIEW



SIDE SECTION VIEW

Figure 2-1. Helical Rotary Screw Expander, HPC Model 76-1 hard tips. The practice of using scale deposits to provide the finished rotor and case dimensions lowers fabrication costs and produces a machine which adapts itself to dimensional changes caused by differing loads, operating temperatures, or pressures.

Large initial clearances for scale deposition make the accumulation of scale a necessity for maximum performance. For example, it can be seen in Figure 2-1 that until scale accumulates to provide the finished dimensions, fluid entering the machine can bypass the high pressure pocket A and pass between the end faces of the rotors and the case directly to the exhaust. It can also enter the high pressure pocket and leak past the rotor tips to region B, then out of B between the rotor end faces and the case directly to the exhaust. In certain positions of the rotors, the cross-sectional area of the leakage paths from the high pressure pocket represent an estimated 25 to 30% of the total enclosing surface. In other positions, the rotors block the entering flow, and the fluid flows along the rotor end faces directly to the exhaust port, bypassing the expansion chambers completely. The leakage of working fluid along these paths severely degrades the performance of the machine. Similar losses occur throughout the machine from regions B through F.

Any successful production well is presumed capable of delivering fluid to the prime mover placed nearby. By the placement of flow control valve T within the expander, the first significant pressure and temperature drop of fluids leaving the wellhead takes place within the expander. As Figure 2-1 shows, the inner face of the valve gate is swept by the rotors. Part of the kinetic energy gained by the fluid in passing through control valve T is delivered to the rotors as impulse.

The expander exhaust porting was designed for the special needs of a two-phase flow machine. Special attention was given to moving the liquid phase through the machine with a minimum of drag or pumping losses. These losses and other deficiencies in the HPC 50-kW prototype adapted for geothermal service showed that a converted compressor designed for gas service is inherently unsuited for geothermal application. The testing of such a machine could produce misleading results.

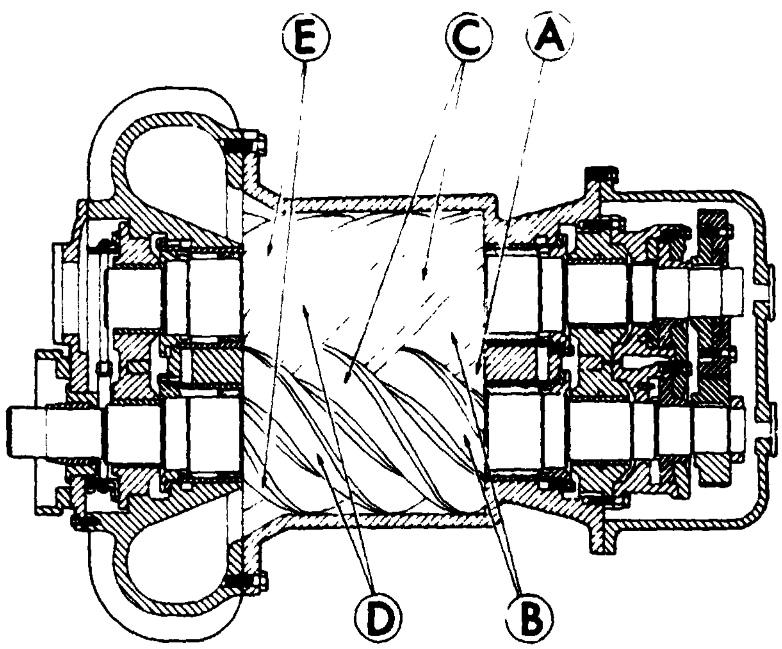
In a detailed analysis of the principles of operation of the expander, either as an aid in understanding the performance of the present design or to serve as a guide for design improvements, it would be appropriate to consider the performance contributed by each of three regions of the machine, namely the inlet region, the central region, and the exit region. As mentioned earlier, in the inlet region the fluid gains kinetic energy, some of which can be delivered to the rotors as impluse. The efficiency of this process is somewhat dependent on geometry and is therefore under some control of the designer. It is in this region also where the inlet porting is changed by the operation of control valve T, Figure 2-1, thus changing the expansion ratio in the central region as the point of inlet cut-off changes. The central region is the region of positive displacement where the fluid expansion can vary from underexpanded to overexpanded depending on load, rotor speed, and inlet and outlet conditions. In the event of under expansion, square card operation takes place in the outlet region much as with air motors. This square card operation allows the expander to handle increased loads beyond those corresponding to full expansion of the fluid within the machine. As the contribution of square card operation increases with load, a point will be reached at which the efficiency begins to decrease. This is true for condensing operation as well as elevated back pressure However, such an analysis is outside the scope of this Project.

2. Design

The HSE design details in this report are limited largely to information released by HPC under the agreement governing its participation in this Project. Some of the details are contained in a descriptive specification prepared by HPC (Appendix A). Additional information can be obtained from Hydrothermal Power Co., Ltd., Post Office Box 2794, Mission Viejo, California, 92690, or from HPC's Final Report: Design, Fabrication, Delivery, Operation and Maintenance of a Geothermal Power Conversion System (Ref. 5), prepared under JPL Contract No. 954404.

During this Project, the expander design underwent three major improvements: the configuration, the method of construction, and the shaft seals. The initial design utilized a cast steel housing in the configuration shown in Figure 2-2. In this configuration, the expander exhausts vertically upward, allowing liquid to accumulate in the exhaust section, blocking it and causing unnecessary back pressure. This disadvantage was corrected in the revised configuration where the exhaust flows downward from the expander (Figure 2-3). In both of these configurations, the rotors must sweep unflashed liquid the entire length of the machine, resulting in pumping losses. In addition, the exhaust porting provided passages unswept by the rotors where scale could accumulate (see Figures 2-2 and 2-3). The transition to a fabricated steel housing provided the opportunity to manufacture the expander in the configuration shown in Figure 2-1. As can be seen in Figure 2-1, this configuration provides unrestricted exhaust porting and a minimum of pumping losses.

These design improvements of configuration and method of construction were completed before fabrication began. HPC consulted CFE engineers regarding construction materials. The improvements in the shaft seal design were made to correct design weaknesses revealed during testing. The original shaft seals were segmented carbon, pressure-backed for oil leakage into the brine. Early failures during acceptance testing were diagnosed as being caused by interference resulting from thermal growth of seal assembly components. Redundant seals were omitted from each assembly to reduce the friction heating, and clearances were enlarged where appropriate. These improvements sufficed for the acceptance testing done with air and for part of the testing in the field in 1978. Additional failures in 1978 demonstrated a need to change the design. The new design used a combination of segmented circumferential carbon seals, floating ring seals, labyrinth seals, and a protective barrier of water seeping through the labyrinth seals into the brine. Oil was maintained behind the segmented carbon seals at a pressure slightly higher than the flush water pressure to prevent



PLAN SECTION VIEW

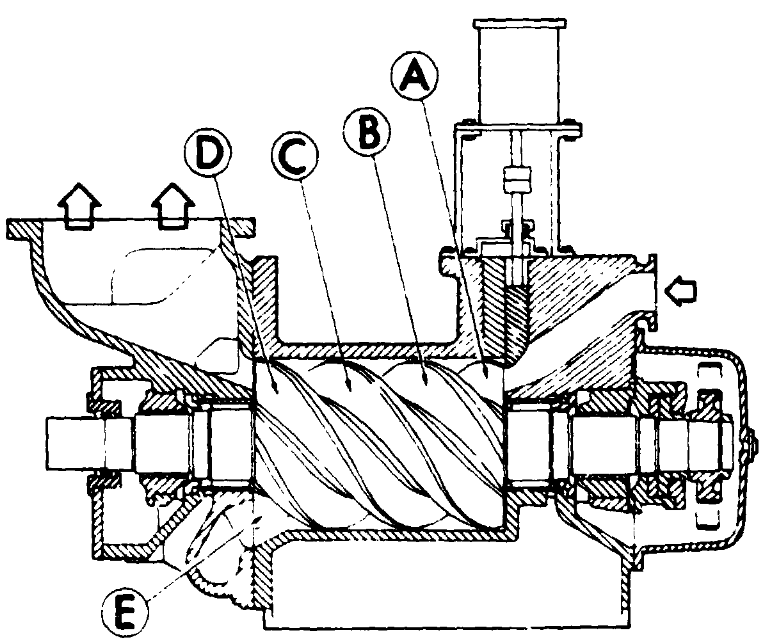


Figure 2-2. Helical Rotary Screw Expander (Courtesy HPC, Notations Added by JPL Technical Project Manager)

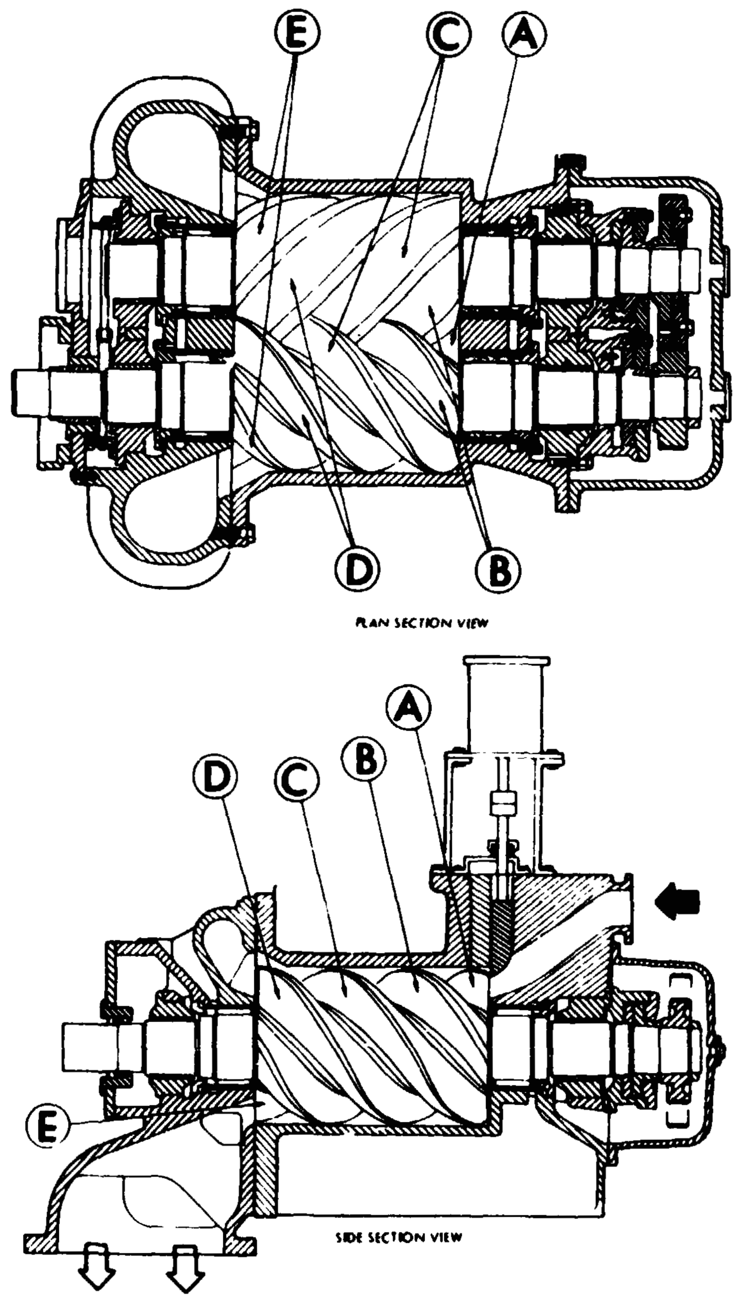


Figure 2-3. Helical Rotary Screw Expander (Courtesy HPC, Notations Added by JPL Technical Project Manager)

water intrusion into the oil. Another important design improvement made during this Project was the modification of the inlet throttle trim to prevent blocking of the inlet passage by the rotor lobe faces, thus eliminating a water hammer detected while operating the expander with compressed liquid feed under highly throttled conditions.

The fundamental design philosophy was that the expander would be a commercial unit of rugged construction utilizing high quality components throughout, each selected or designed for long service. In principle, the design would depart only slightly from the technology of the existing compressor industry so that production of many units would not represent a technological problem. The selection of the 1000-kW size was intended to provide a machine large enough to provide a credible commercial evaluation, yet small enough to permit versatile testing on a single well. The result was a machine with two mating 16-1/2 inch diameter, helically-grooved rotors, 25-inches long (see Figure 2-1). The male rotor is the driver and has four lobes, the female six. Thus, for a 3000-rpm output shaft speed, the female rotor turns at 2000 rpm. Sychronizing timing gears were used.

The rotors were machined from solid, one-piece Type 410 stainless steel forgings to provide sufficient strength for 100-psi differential pressure across the rotors at speeds up to 5000 rpm. The rotors are supported in tilt-pad radial bearings and are positioned by self-equalizing thrust bearings. The lobes and end faces of the rotors were hard tipped to provide wear-resistant surfaces to limit the growth of scale on the opposing surface. The rotors, rotor housing midsection, and low pressure end were fabricated of Type 304 stainless steel as a concession to the oxidizing conditions expected during intermittent evaluation testing. The housing high pressure end was fabricated of Type 4142 corrosion resistant steel. (In contrast, the 50-kW prototype discussed in Section I.C. and in the published paper in Appendix C was carbon steel throughout.)

The housing was hydrostatically tested to meet ASME Boiler and Pressure Vessel Code - Section VIII, Rules for Construction of Pressure Vessels. The inlet and high pressure regions were isolated from the midsection and were hydrostatically tested to 1080 psig to meet or exceed a 300-pound ANSI rating. The midsection and low pressure regions were tested at 450 psig to meet or exceed a 150-pound ANSI raised-face flange rating. The maximum allowable feed condition is 625 psig at 500°F.

The gate-type throttle, or governing valve, T, (see Figure 2-1) is regulated hydraulically by a signal from a mechanical flyball-type governor acting through a hydraulic servo-mechanism. The governor system hydraulics draws oil from the same oil system which provides lubrication and cooling for the expander bearings and shaft seal assemblies.

C. POWER PLANT

The principal components of the HSE power plant are the expander, a speed reducer and an alternator, mounted and aligned on a structural steel base, and a lubrication oil console. The power plant is described by HPC in the descriptive specification in Appendix A, and is shown diagrammatically in Figure 2-4. The main assembly is 6-feet wide, 8-feet 1-inch high, 25-feet long, and weighs approximately 25,000 pounds, as shown in Figures 2-5 and 2-6 (see also Figure 1-1). The gear box is shown connected to the expander in Figure 2-7, and the oil console and fan-cooled heat exchanger are shown in Figure 2-8.

As stated earlier, the power plant was designed to operate as a self-contained unit. A design objective is outdoor, unattended operation for extended periods. The plant has its own controls, panel-mounted instruments, and a safety shutdown system to provide protection against equipment faults. All equipment necessary for starting on geothermal fluid is mounted on-board. The instruments measure and display alternator frequency, voltage, current, kilowatt hours and elapsed time. Controls for frequency, voltage and generator output breaker are mounted on the instrument panel. For test purposes, provision was made for remote adjustment of frequency and voltage. The fault protection system monitors underspeed, overspeed, oil supply overtemperature, oil supply underpressure, shaft seal low differential pressure, shaft seal low flush water flow, and vibration. The protection system works in conjunction with an on-board automatic stop (AS) gate valve in the feedline to the expander. A blocking valve and the AS valve are shown installed in the feedline in Figure 2-9. The AS actuator can be seen in Figure 2-8. An overspeed fault and emergency stop button near the instrument panel cause this valve to close fully within 1 second. A normal stop button on-board, and all other fault conditions, cause this valve to close within 15 seconds. Provision was also made for control of emergency stop and manual stop remote from the power system. The expander throttle valve is closed by controls which override the governor to provide a back-up emergency stop, sequenced to occur just after the automatic stop valve signal occurs.

The power plant was designed to produce 60-Hertz power from the alternator operating at 1800 rpm. Since the optimum speed of the expander is not known, the speed reducer was supplied with three gear sets to permit investigating the expander performance when operating the power output shaft (male rotor) at speeds of approximately 3000, 4000 and 5000 rpm. JPL required a vibration and torsional analysis for all three gear sets. No vibration nodes appeared within the speeds corresponding to the three gear sets.

Safety considerations were given to the consequences of seizing, or jamming, of the expander rotors. The expander and the speed reducer both have pairs of contrarotating parts, although not of matching inertias. Thus, neither drive train component has appreciable net angular momentum. Only the alternator does, since it has a single rotating part. Therefore, a shear coupling was installed between the speed reducer and the alternator so that the alternator could continue to rotate if the expander and speed reducer stopped abruptly. Little or no overturning momentum would be applied to the power plant main assembly. In

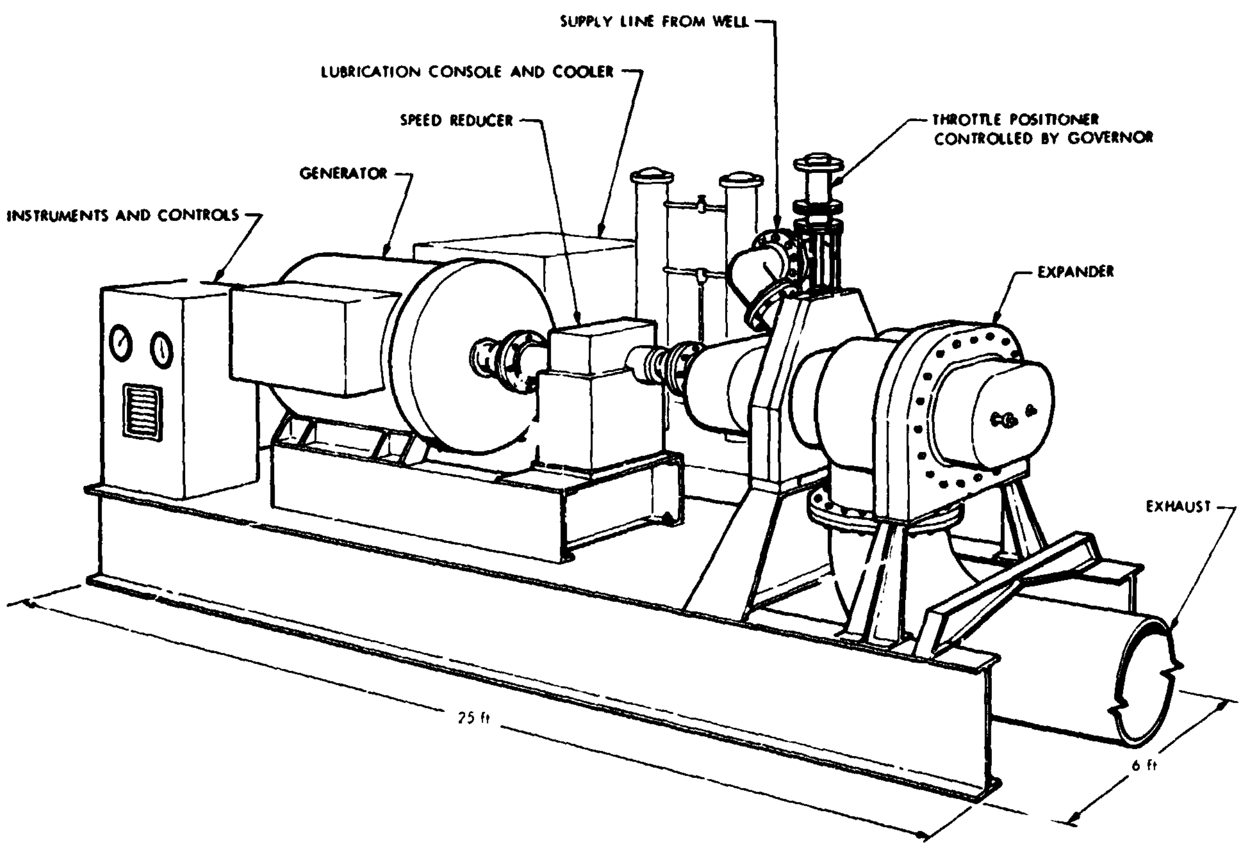


Figure 2-4. Helical Screw Expander, 1-MW Power System (Courtesy HPC)

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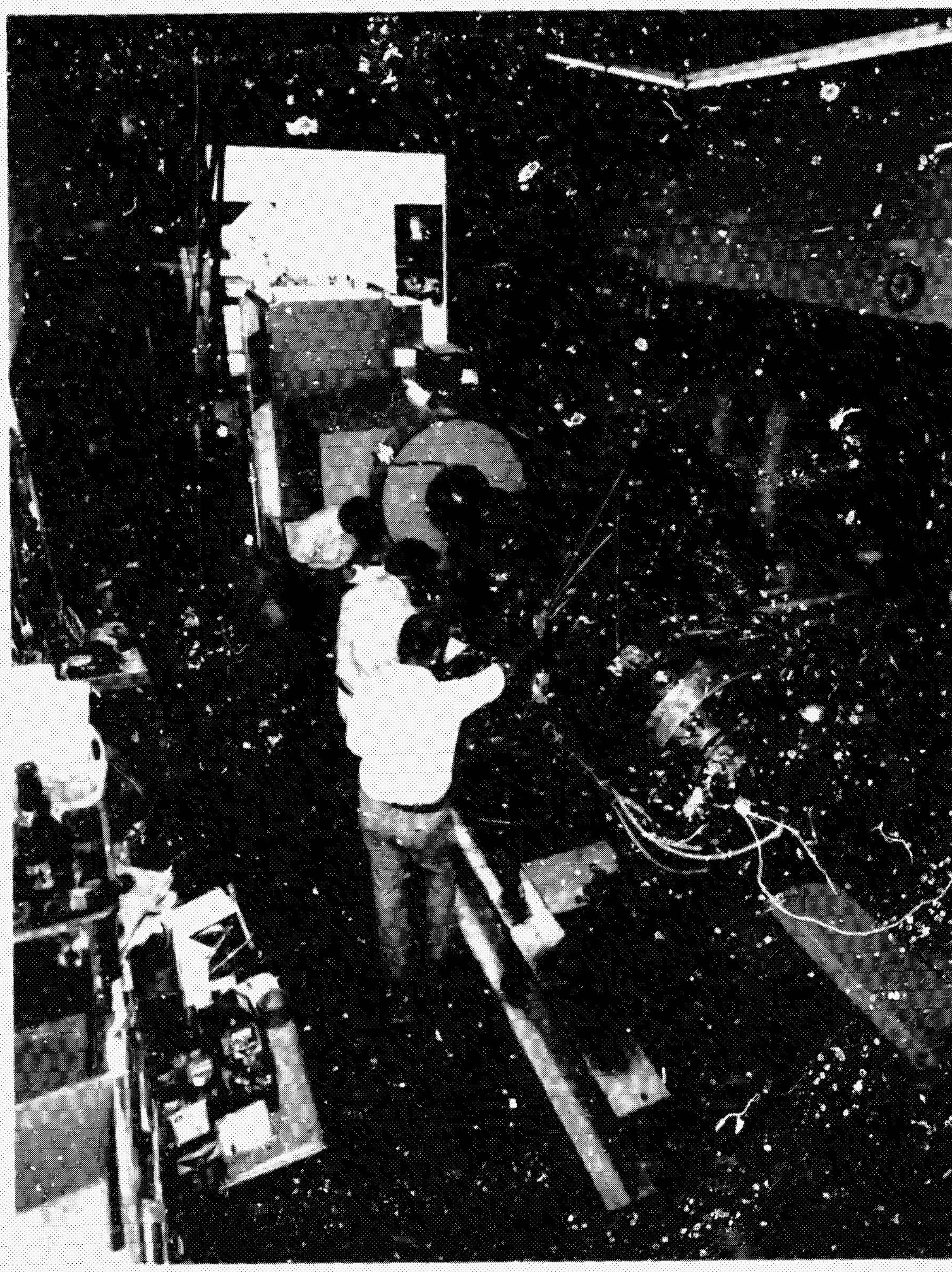

Figure 2-5. HSE Power System Undergoing Inspection

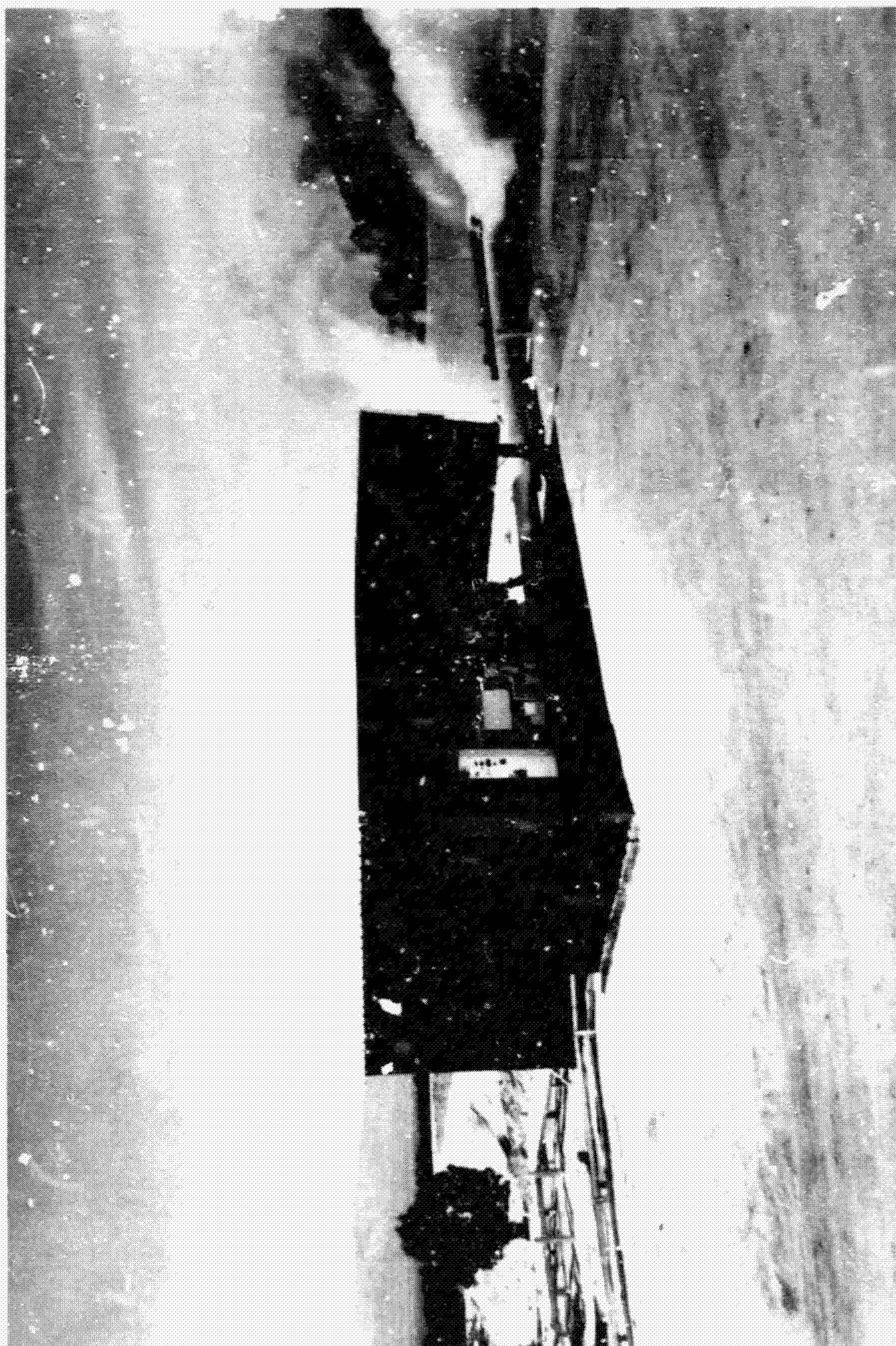

Figure 2-6. HSE Power System Undergoing Testing

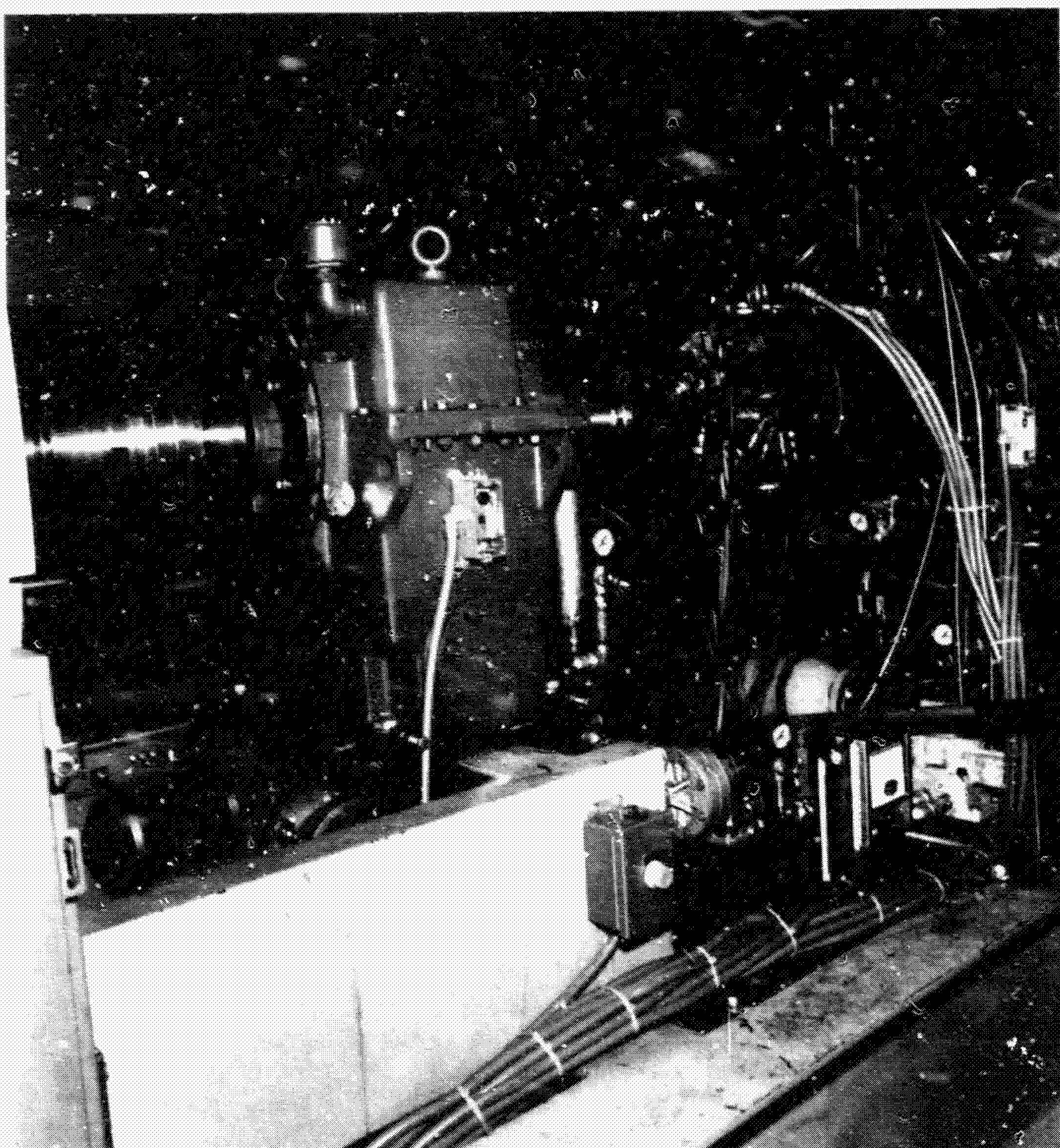

Figure 2-7. Gear Box Connected to HSE

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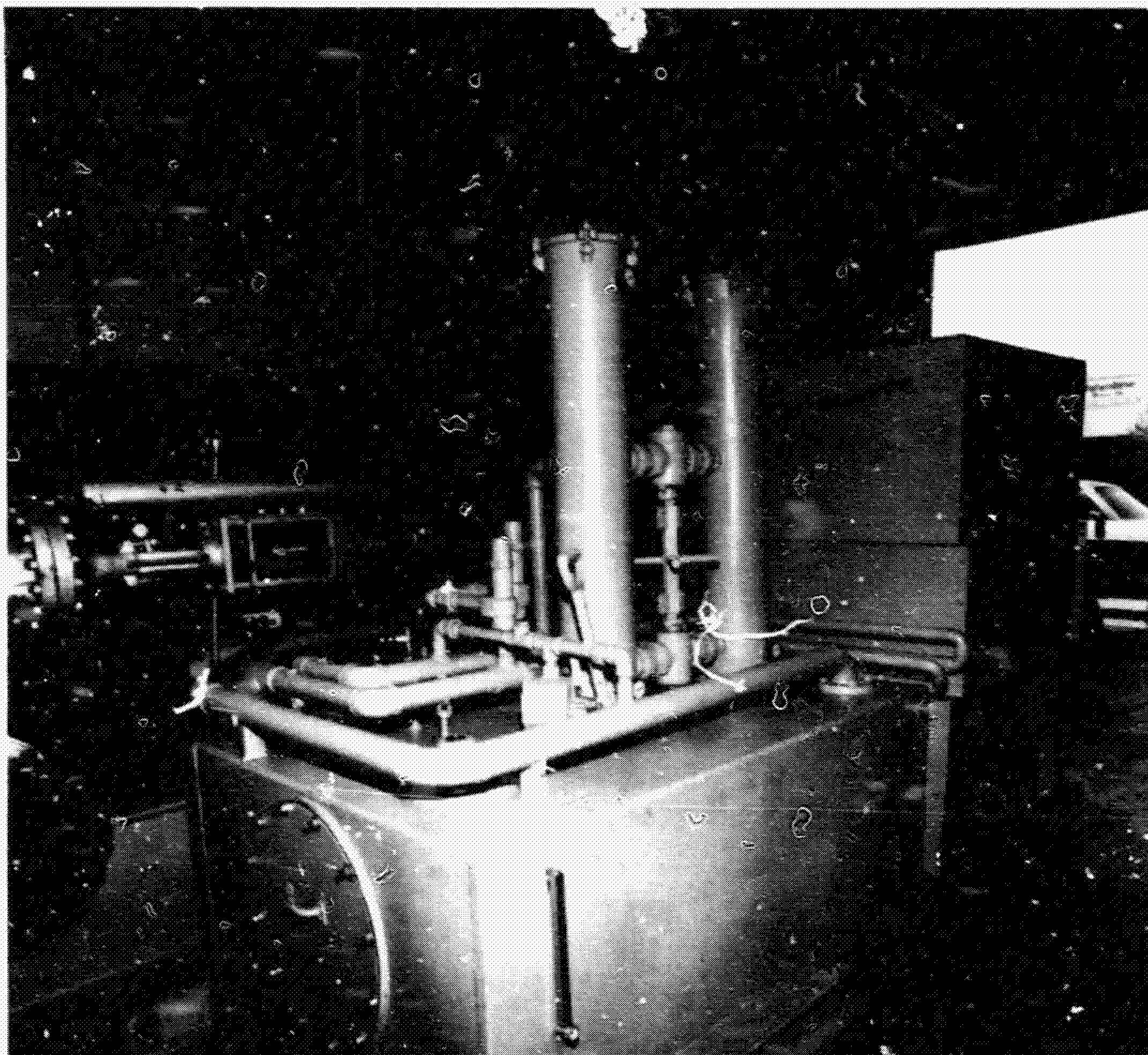

Figure 2-8. Oil Console and Fan-Cooled Heat Exchanger

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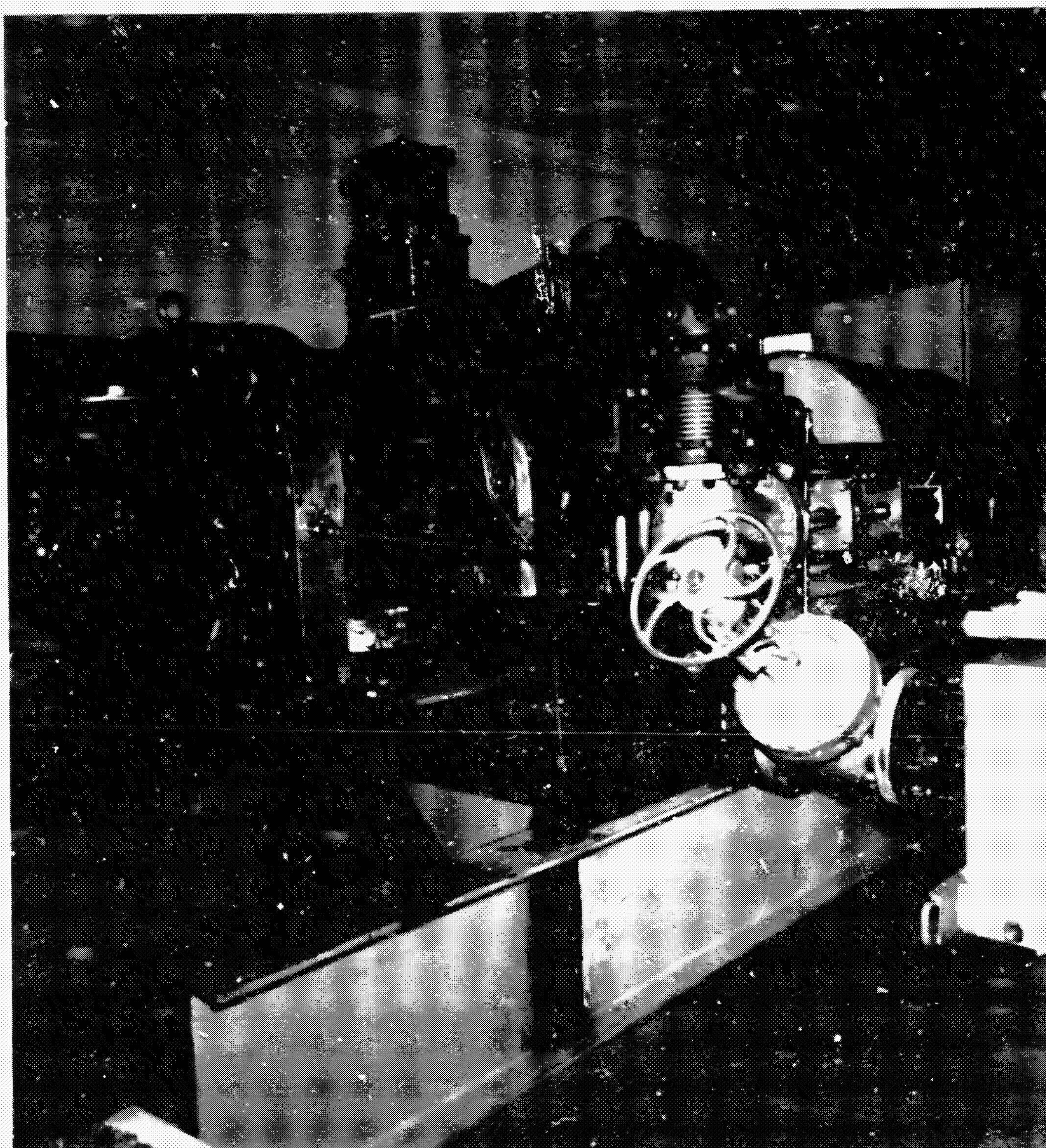

Figure 2-9. Blocking Valve and Automatic Stop Valve in HSE Feedline

addition, an analysis made by HPC of the consequence of transferring the angular momentum of the alternator to the main assembly under free-standing conditions showed that the assembly would not be overturned for a normal installation. The benefits of the process piping connections to the expander were not included in the analysis.

The testing of the HSE in 1979 to confirm the adequacy of the overhaul revealed the need to install a water separator to remove flush water which leaked into the oil passing through the new seal assemblies. Also needed was a non-pulsing pump for supplying the flush water. The need for a jacking motor was also confirmed. The needed hardware was installed by HPC in Mexico under DOE contract. The installation was outside the scope of this Project. The hardware is included in the description specifications (see Appendix A). The conversion of the power plant to 50-Hertz operation by HPC in Mexico with DOE funding prior to shipment to Italy is not included in the descriptive specification.

D. LOAD BANK

A 1000-kW transportable load bank (Figure 2-10) was provided for imposing a variable electrical load on the power plant for test purposes at any test site. A captive load such as this permitted a test flexibility which would have been impossible otherwise. The load bank consisted of two 6-foot duct heaters, each with blowers and relays and a switch panel (Figure 2-11) to permit manually adding or removing electrical load in units of 50 kW or more. The resistive load units were two 50-kW, two 100-kW, one 200-kW and one 500-kW. Each increment loaded the three phases of the alternator equally through the use of matched lengths of four-wire 500 MCM cable per phase. Each fan was monitored by an air-flow switch, and protective interlock circuitry required that both fans be in operation before the main breaker on the load bank could be closed. Thus, the first load increment was an inductive load of approximately 10 horsepower from the two fans. In addition, each duct section was protected with three thermal switches, each interlocked with the main breaker. Electrical interlocks were also provided on the doors covering the fuse panels and terminal box. The load breakers were provided with trip coils to permit load shedding according to an independent logic. The two 100-kW loads were shunt-trip connected to two waste water pumps so that 100 kW could be shed upon starting either pump, provided the corresponding load was on-line. After shedding, the circuit breaker could be reset and reloaded. The load bank was provided with fault condition switches so that shutdown by failure of either fan, or by thermal overload, could be detected by the computer. Fitted weather-proof slipcovers were provided for the fan shrouds separately, and for the rest of the structure. Lift points for a fork-lift truck were provided in the base structure.

E. DATA SYSTEM

1. Functions

The data system was designed, fabricated and operated to perform the following functions:

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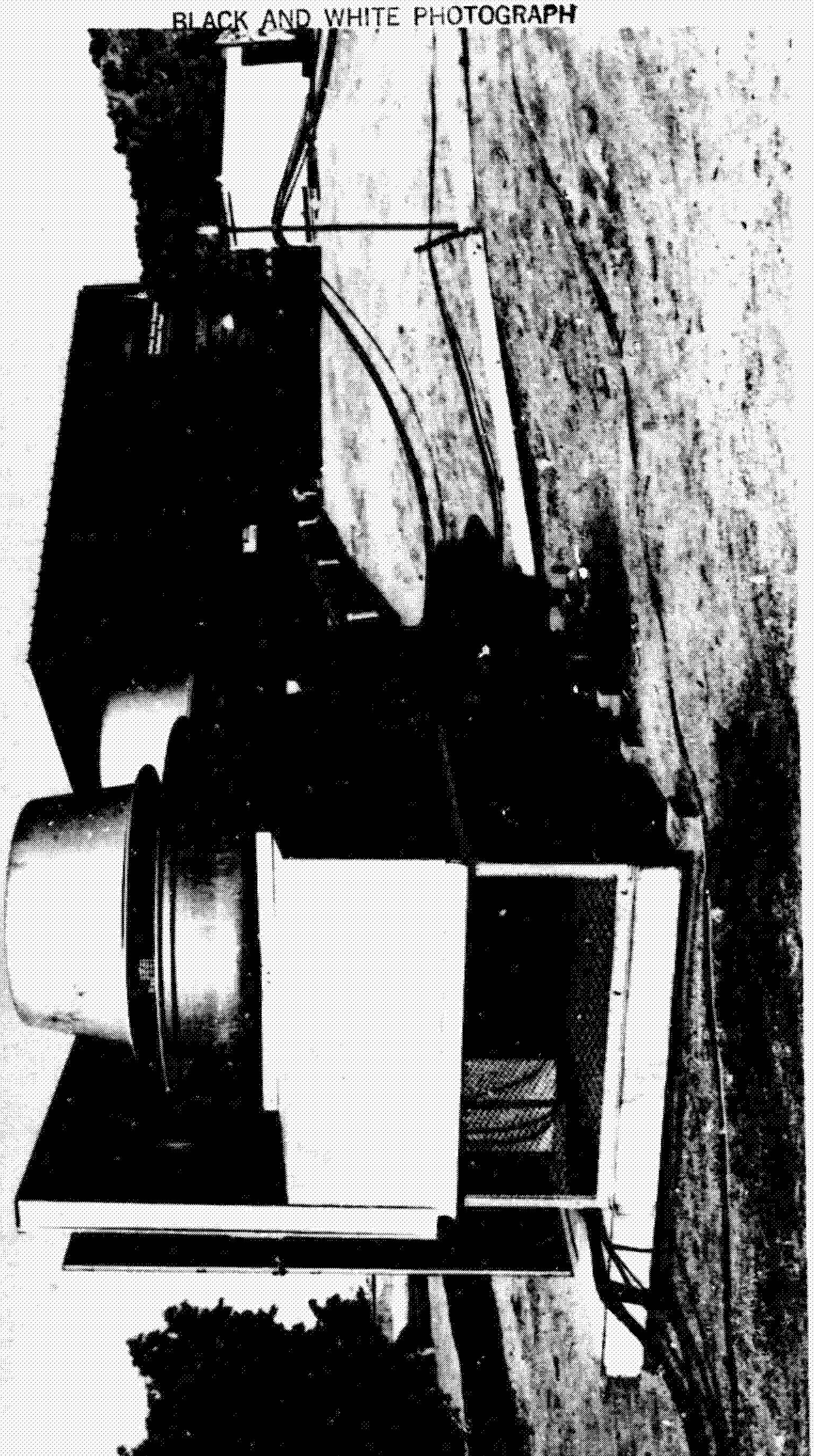

Figure 2-10. 1000-kW Transportable Load Bank

Figure 2-11. Load Bank Showing Switch Panel

(1) Collect data from transducers in the power system and the test process.

(2) Reduce the data and calculate the performance of the expander.

(3) Display the test parameters and performance versus time on printed logs to provide process control assistance on a permanent record.

(4) Record the data on magnetic tape automatically, or at operator discretion.

(5) Monitor the safety shutdown system in the HSE power system for first fault, and record the fault and one complete set of measured data existing just before the fault occurred.

(6) Monitor operating parameters and provide a warning in the event of an "out-of-range" condition.

(7) Process the test results by retrieving the data stored on tape and analyzing it, and printing or plotting the results in a variety of ways according to operator instructions.

2. Objectives

Many objectives and factors were considered in designing the data system and selecting the equipment.

a. Precision and Stability. It was considered necessary that the data system be precise and stable so that the approach to steady-state operation of the HSE could be monitored during periods of scale deposition within the machine. Because of loading and thermal effects, the dimensions of the expander rotors and case were expected to change slightly as operating conditions were changed, abrading scale away from some areas and opening up clearances in others. With continued operation, scale deposition would occur providing new finished dimensions and restoring performance lost because of the new clearances. For an optimum test well, this process was predicted by HPC to occur within a few hours.

b. Accuracy. A target accuracy of two percentage points was chosen for efficiency determination. An error analysis based on perturbation theory was made to determine the requisite accuracy of each measurement for each candidate test process. This information was used in writing the specifications for the data acquisition. Subsequently, an uncertainity analysis showed that a root mean square uncertainty in efficiency determination of less than 5% could be expected for all tests.

c. Environmental Control. The harsh environment expected in the field made it necessary to provide a controlled environment for the computers and other data acquisition hardware. This was accomplished by outfitting an insulated trailer with suitable instrument racks, table space, lights, a vestibule and air conditioning. The instrument trailer is known as the Data Van in this Project and is described more fully later.

d. Stable Power Supply. An uninterruptable power system (UPS) was installed in the Data Van to provide reliable, regulated power to the data system. The UPS utilized an inverter which drew power from batteries to give voltage and frequency regulation. The batteries were maintained with an UPS battery charger during normal operation, but provided approximately 15 minutes of operation in the event of loss of source power. This arrangement allowed for drawing operating power for the data system from the HSE power system without concern for frequency variation or unplanned shutdown during the testing. This also allowed for adjusting the HSE power system output voltage as a means of adjusting the system load during the tests. The UPS can relay the unregulated source power to the data system.

e. Auxiliary Power. In the test planning, it was assumed that the test sites might not have electrical service. Therefore, provision was made to supply standby power from an engine generator for pre-test and post-test instrument calibrations and for general test preparations. Two old engine generators borrowed from JPL for this purpose failed, one in 1978 and one in 1979. As a consequence, four other units were used at different times, two in the nearby Phillips test installation, one in a mobile office used by the Project, and another borrowed from JPL. The lost time, repairs and extra shipping cost more than a new one would have.

f. Calibration. In the selection of process instruments, calibration in the field was a desirable factor. Calibration equipment was provided for the field calibration of pressure and differential pressure transducers, and for temperature measurements. The flow meters were not field-calibrated. The orifice meters, whose measurements were critical to the test results, used orifice plates and meter runs manufactured to specifications in conformity with ASME standards. The vortex-shedding flow meters used meters runs with corresponding specifications and factory-calibrated frequency-to-current converters. The kW and kWh instruments were checked against one another, and were post-calibrated by the manufacturers. The frequency instruments were calibrated against the local utility power before being sent to Utah.

g. Spares. Some redundancy was provided in spare parts and instruments for the data system although the spare parts list tended to be highly selective and not large. The small inventory of spares permitted instrumenting the Phillips' FTF separator for pressure and level. The JPL process installation was also instrumented part way through the tests to measure waste tank level and waste pump pressure for additional process information which was used to good advantage in performing the tests.

h. Field Mobility. The equipment layout and assembly was done with the awareness of the need for mobility to allow installing the test equipment at successive test sites. This led to the test array concept discussed in Section II.G.

i. Signal Compatibility and Processing. The transducer signals can be grouped as follows; 0 to 1 mA, 4 to 20 mA, 0 to 20 mV, frequency and resistance. Signal conditioners converted these signals into voltages of 0 to ± 1 Volt, which are compatible with the desk-top computer used in the data logging. The 0 to 1 mA and 4 to 20 mA signals used 1000-ohm and 50-ohm load resistors repectively to provide the requisite voltage signals. The frequency signals from the vortex-shedding flow meters were converted to 4 to 20 mA signals. All voltage and amperage signals varied linearly with the variations in the measured parameter over the region of interest. Platinum resistance thermometers were used with bridge completion assemblies, some of which used linearizing amplifiers to provide high accuracy linearized output voltage signals.

3. Data Identification and Treatment

The voltage signals for 43 parameters were read into an X(J) vector by the computer, converted into appropriate parameter units by the following equation, and stored in an a and b matrix:

$$a(J) + b(J)\ X(J)\ \text{Volts} = X(J) \qquad (1)$$

The coefficients a(J) and b(J) were determined by calibration, where appropriate, and the calculated and input values of the parameters were compared. In this way the transducer linearity and calibration accuracy were verified. For purposes of illustration and reference, the final calibration coefficients of the Utah testing are given in Appendix B.

4. Data System Hardware

The principal data system equipment, other than the transducers, is listed in Table 2-1. The pressure and flow transducers, all of which produce a 4 to 20 mA signal, are listed in Table 2-2. The temperature transducers are listed in Table 2-3 and the remaining transducers are listed in Table 2-4. The power supplies, signal-conditioning equipment, computers, printers and interfacing equipment of the data system are shown in Figures 2-12 and 2-13. The data system is described in more detail in a data system hardware manual (Ref. 3).

5. Data System Software

In the course of test preparation, testing and data analysis, numerous computer programs were developed, some of which became obsolete. The early calibration and installation programs for the data system were written by JPL, but were later superseded by operating programs which were developed in the field during test operations as the data system usage and expander test procedures were refined. All operating programs and data analysis programs were written by Dr. E. F. Wahl of Wahl Co., Claremont, California, a, were the final calibration programs. Some of these programs make use of the earlier JPL programs. The operating and analysis programs utilize a subroutine for the termodynamic properties of steam adapted by Bosco Engineering, Whittier, California, from a United States Department of the Navy Fortran program and procured from Bosco Engineering for use in this Project. Fifteen of the most useful programs were documented in a software manual (Ref. 4) prepared by Dr. Wahl. These programs are:

CALIBRATION PROGRAM SET
- Transducer Calibration
- Calibration Data File Correction
- a & b Calculation
- a & b Calculation Using Selected Data Sets
- Enter a & b Values into Data File

OPERATING PROGRAM SET
- Initialize Data Cassettes
- Enter Faulting Device Names
- Enter TDS and CO_2 Concentrations
- Enter Orifice Sizes
- Operating Program I: Start-up Program
  (Includes Operating Program III: Shutdown Program)
- Operating Program II: Main Operating Program
- Operating Program III: Shutdown Program
  (Includes Operating Program I: Start-up Program)

DATA ANALYSIS PROGRAM SET
- Raw Data Operating Log Calculations
- Instantaneous Data to Averaged Data Conversions

Table 2-1. Principal Data System Equipment

Quantity	Description
	Instrument rack containing:
1	Uninterruptable power supply with inverter, batteries and battery charger; Deltec Corporation, DSU 1210
	Instrument rack containing:
2	24-VDC power supplies for field transducers; JPL
1	20-channel bridge amplifier for resistance temperature transducers; Hy-Cal Engineering; Model ESD-9025-C
1	6-channel high accuracy modular bridge amplifier with linearized output, matched to resistance temperature transducers; Hy-Cal Engineering; Model ESD-4050-A
1	Multiprogrammer; Hewlett-Packard; Model 6940 B
1	Multiprogrammer interface; Hewlett-Packard; Model 59500A
1	Digital calendar clock; Hewlett-Packard; Model HP-IB 59309A
1	Fast analog strip chart recorder with 12-channel signal attenuator; Honeywell; 1508 Visicorder
2	Flow integrators; Rochester Instrument Systems
1	10-VDC power supply and signal conditioner for thrust bearing load cells; Revere Corporation of America
2	Signal conditioners, flow integrators and rate meters all wall mounted for two vortex shedding flow meters; Neptune Eastech

Table 2-1. (Cont'd)

Quantity	Description
	Instrument rack containing:
1	Frequency meter, panel mounted
1	Volt meter, panel mounted
1	Kilowatt hour counter for monitoring kWh logged at HSE power plant
1 each	Voltage, frequency, stop, and emergency stop remote control for the power plant, panel mounted
1	Waste tank high and low level alarms and alarm silence controls, panel mounted
	Table with:
2 (1 in 1978)	Computers; Hewlett-Packard; Models 9825A
1	Calculator; Hewlett-Packard; Model 97
1 (1978 tests only)	Printer, Hewlett-Packard; Model 2671A
2 (1979 tests only)	Printers; Hewlett-Packard; Model 2631A
	Accessories:
1	Aneroid barometer; Wallace & Tiernan; Model 62A-4A-0100, 0-16 psia
1	Low pressure calibrator; Wallace & Tiernan; Series 1500, 0-280 in. H_2O
1	Dead weight tester; Ashcroft; IBX 8558, two piston; 0-3250 psi
1	Decade resistor; General Radio; Model 14327
3	Transmitter/receiver radios; General Electric; Mastr PE56RASAHX

Table 2-1. (Cont'd)

Quantity	Description
1	Personal Radio Charger Rapid Three with microphone; General Electric
2	Communication headsets for noisy areas; David Clark Co., Inc.; Straightaway; Model No. 12510G-02/C1-636-11

Table 2-2. Pressure and Flow Transducers[a]

Symbol	Make	Model	Range	S/N
Ps	Gould/ Statham	PA-1000-1000-15	0-1000 psia	15001
Pf	Gould/ Statham	PA-1000-1000-15	0-1000 psia	15000
P2	Gould/ Statham	PA-1000-0050-15	0-50 psia	15007
Mf	Rosemount	1151DP4E22MB	(0-25/180 in.)[b] 0-180 in. H_2O d	90722
Mv	Rosemount	1151DP4E22MB	(0-25/150 in.) 0-100 in. H_2O d	95286
Pw	Gould/ Statham	PG-1000-1000-11	0-1000 psig	12172-A
Pv	Rosemount	1151GP8E22MB	0-1000 psig	64061
P1	Rosemount	1151GP8E22MB	0-1000 psig	64062
Mw	Neptune/ Eastech	4105-050-031-100-0	0-400 gpm[c]	7710111-1
Mv	Neptune/ Eastech	4105-050-031-210-0	0-400 gpm[c]	7710111-2
Ls	Rosemount	1151DP5E22MB	(0-125/750 in.) 0-750 in. H_2O d	89379
Lw	Rosemount	1151DP5E22MB	(0-125/150 in.) 0-750 in. H_2O d	89377
Spare	Rosemount	1151DP5E22MB	(0-125/750 in.) 0-750 in. H_2O d	90085
Spare	Gould/ Statham	PA-1000-0050-15	0-50 psia	15004

[a]Accuracy 0.25% of calibrated range.
[b]Parentheses denote variable range.
[c]Vortex-shedding flow meter.

Table 2-2. (Cont'd)

Symbol	Make	Model	Range	S/N
Pd	Gould/ Statham	PG3000-01M-12-11	(0-200/1000) 0-1000 psia or psig	
P_A	Gould/ Statham	PG3000-200-12-11	(0-40/200) 0-200 psia or psig	
P_A	Gould/ Statham	PA1000-0200-15	0-200 psia	15002
P_B	Gould/ Statham	PA1000-0050-15	0-50 psia	17123
P_C	Gould/ Statham	PA1000-0050-15	0-50 psia	

Table 2-3. Process Temperature Transducers

Symbol	Length, in.	RTD No.
T_s	4	91
T_o	4	90
T_f	4	88
T_v	3	98
T_1	4	95
T_2	6	94
T_r	3	99
spares	2 @ 3 1 @ 6	

Platinum, 100 ohm at 0 °C = 0.00385 ohm/ohm/°C (nominal), 3 wire.

Table 2-4. Other Transducers

Symbol	Make	Model	Range	Signal	S/N
Th-Brg				0-20mV	
V	Scientific Columbus	VT-11022		0-1 mA	
I	Scientific Columbus	CT510A2		0-1 mA	
Freq	Scientific Columbus	6284A	55065HE	0-1 mA	
kW	Scientific Columbus	DL31K5A2-2	0-1200 LW	0-1 mA	
Th%	Bourns	5184		0-5000 ohm/ 4 in.	PNZ051840405-1

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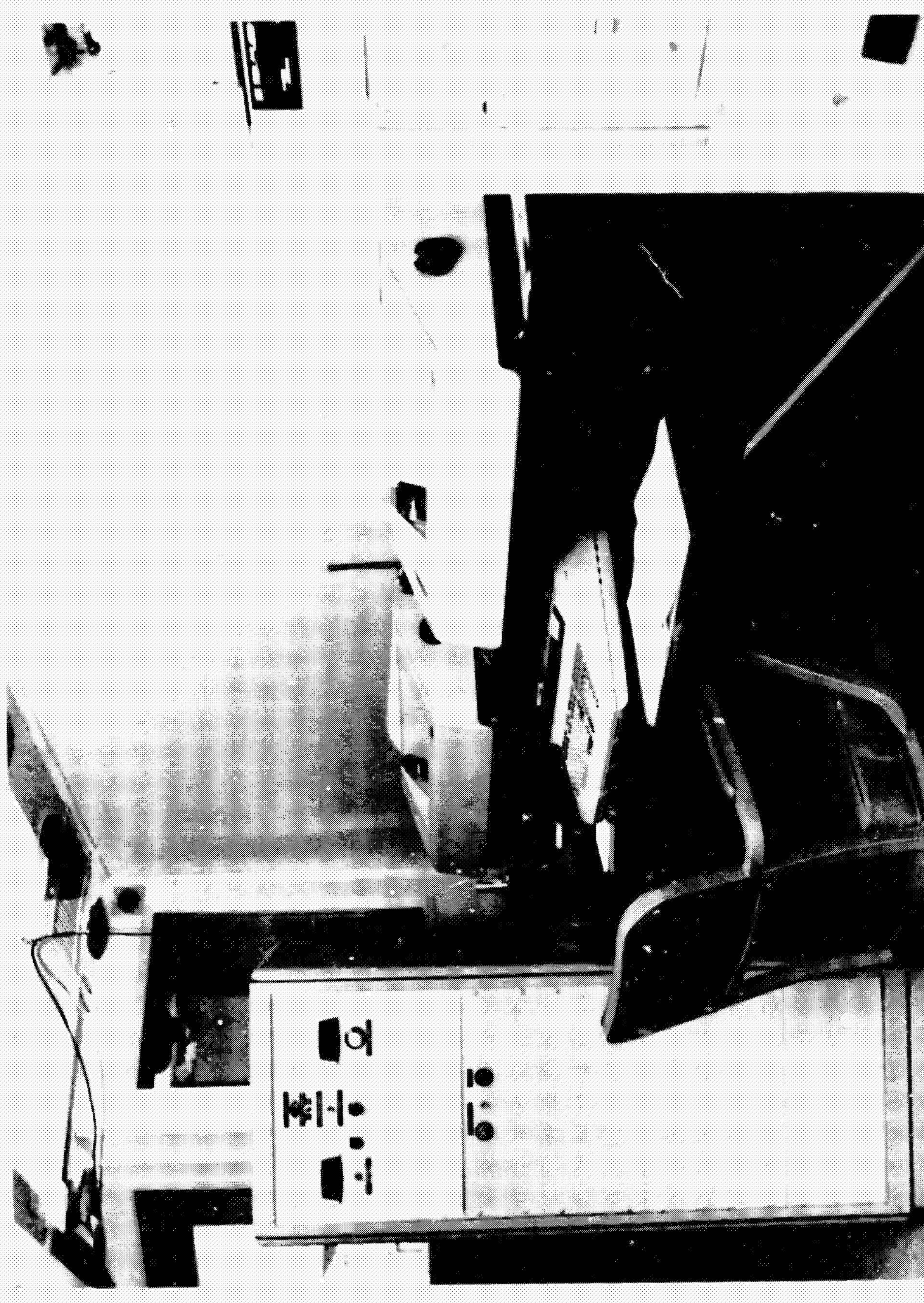

Figure 2-12. Control Panel, Printers, Operating Computer, and Instrumentation Rack in Data Van

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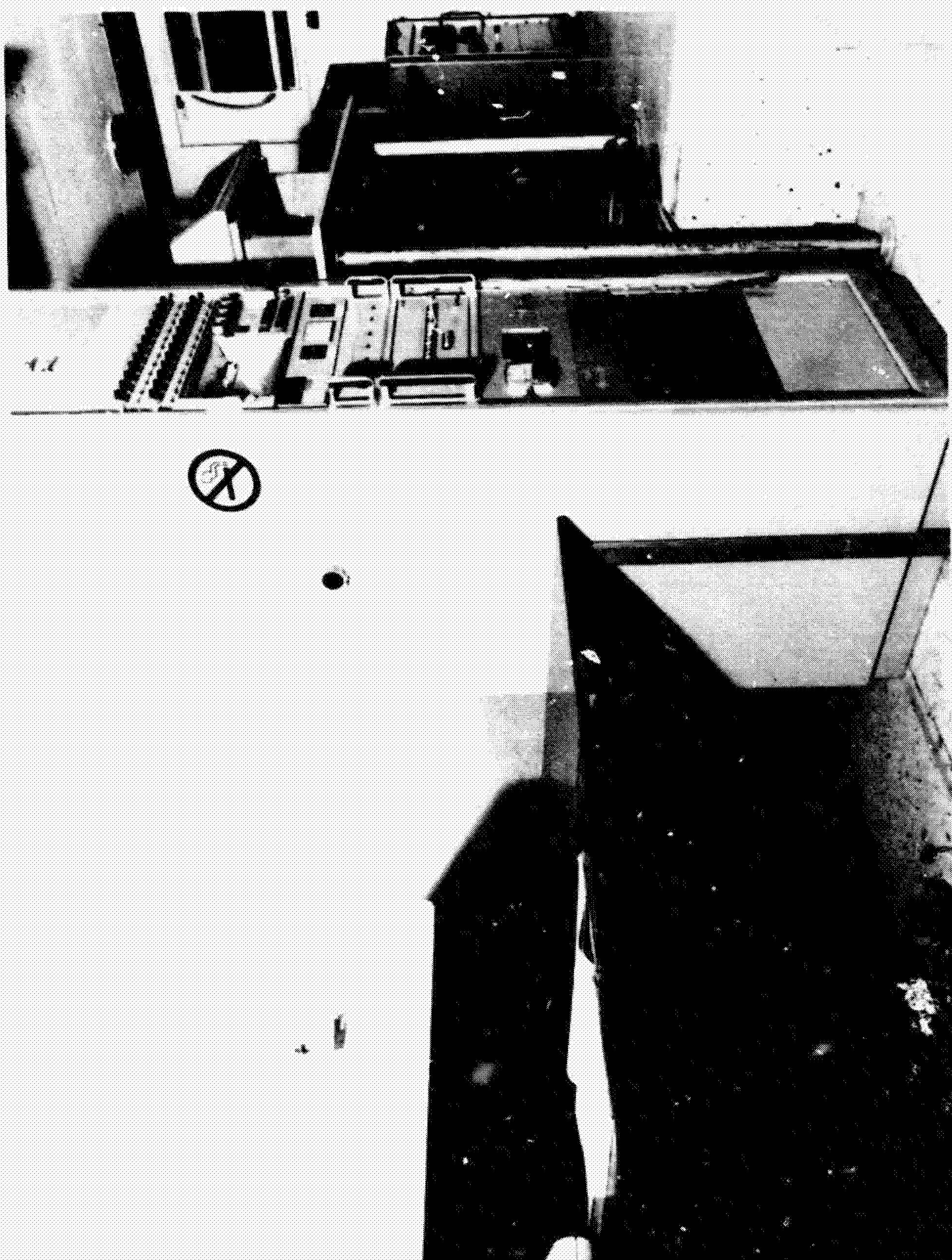

Figure 2-13. Operating Computer, Printer, Instrumentation Rack, Printer/Plotter, Uninterruptable Power Supply, and Air Conditioner in Data Van

Averaged Data Calculated and Results Stored in
Z Matrix
Data Management of Z Matrix Data
Plot Analysis of Z Matrix Data

6. Display and Logging of Data

The displaying of data was accomplished by the operating computer on one or more printers. In the test planning calculations, P was used to denote power, p was pressure, t was temperature, X was steam quality, $\dot{m}$ was flow rate, and subscripts were used to identify which one. Thus p_1, t_1, and X_1 indicated expander inlet conditions. A conflict arose with the use of the computer, because the printers cannot print subscripts, and X was used by the programmer to identify a data matrix. Therefore, the expander inlet conditions were logged as P1, T1 and Q1, and flow was logged as M. P without a subscript, or suffix, was always shaft output power, but it was tabulated as kWs, whereas kW was logged for alternator output. These transformations are typical throughout this Project. Therefore, p_D and Pd are equivalent, and p_S and Ps are equivalent. So are THROT% and Trt% and T% and th% and Thr%.

During the acceptance testing of the HSE power plant in 1977, and during the early field testing in Utah in 1978, the measured and calculated parameters were displayed on the 2-1/4 inch wide thermal printer of the computer (Figure 2-14). After the field testing began, programming changes were initiated to display the data with a 17-inch wide impact printer, leaving the thermal printer available for special displays. Examples of these special displays are the machine status, process status and performance results (Figure 2-15). A sample of the impact printer data display for the 1978 testing is shown in Figure 2-16, in which the test data and process parameter nomenclature are identified across the top. The print frequency could be varied by operator instruction to provide suitable monitoring of the process status. Process variation was easily detected and when the condition of steady state was reached, 10, 20, or 30 complete samples of unprocessed data were logged as sets on tape by the computer in response to operator instruction. The computer logged the event and identified these data sets by number.

For the 1979 testing, two higher speed printers were used (see Figure 2-12). The right hand, or operating printer, provided a permanent record of data logged at a minimum frequency of about 12 seconds which included the calculation of expander efficiency, as in 1978. Figure 2-17 shows Run No. 13, November 13, 1979. (The data showing inert gas content in the steam has been deleted from this table and elsewhere in this report because it is proprietary information not yet released by Phillips for publication.) The parameters displayed, which were used in the calculations, were averaged values, which tended to mask variations in the process. The second printer displayed unaveraged values of most of the process parameters in larger print without taking the time to calculate the efficiency. This record was a fast response log, useful for scrutinizing the status of the process in detail during process adjustments, or prior to recording

```
----------------
03/16   11:18:00

 VOLT     CUR
   0.0      0.0

 FREQ     KW
  55.0      0.0

  P0      T0
  269.8   402.8

  Mf      Mv
   -0.6    -0.8

  Pf      Pv
  265.6   250.5

  Tf      Tv
  403.4   384.8

  Ts
  402.8

  P1      T1
   44.9   284.4

  P2      T2
   12.3   201.9

  Mr      Tr
  -12.3   304.6

  Mw    THROT %
  -12.3    43.7

    E BRG T
 113  105  113
 109  123  117

    A BRG T
    48      43

    A WDG T
  35   39   36
   0   37   38

   TH BRG F
   219     29

----------------
```

```
----------------
04/05   17:20:00

   KW    THROT %
   76.2    32.2

   Ts      Tr
   382.9   189.7

   To      P1
   347.3   104.2

   Tf      T1
   349.0   331.8

   Mf      Pf
    24.2   205.6

   Mr      Fw
    41.3   447.9

   Mw      Ps
   175.3     0.0

   T2      P2
   200.9     2.7

  VOLT     CUR
   473.1   102.8

  FREQ     Tv
    60.2   258.4

     E BRG T
  157  147  151
  156  171  163

     A BRG T
     78     69

     A WDG T
  102  100   98
    0  107  107

    TH BRG F
    518    127

----------------
```

Figure 2-14. Examples of Thermal Printer Operating Logs as Produced by Early Operating Programs

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```
****************
05/14   13:37:02

RECORDED
# of files  10.0
last #     303.0
run #       38.0
****************
05/14   13:38:20

PERFORMANCE DATA
----------------
LIQUID
 T          355.4
 P          160.4
    Mf      88125
VAPOR
 T          357.7
 P          153.0
    Mv      15471
INLET
 P          140.4
 T,exptl    351.1
 T,calcd    353.5
 Q,%         15.1
 Mf+Mv     103596
EXHAUST
 P           12.3
 T,exptl    200.4
 T,calcd    203.2
 Q,%,i       25.1
 Q,%,act     27.1
OUTPUT
 ENGINE,IDEAL
 Btu/#       39.9
    kw       1212
 Ds           1.2
 Ns          20.3
ELECTRICAL,EXPTL
    kw        515
  amps        628
 eff,%       46.9
THROTTLE,%   79.1

****************
*PROCESS STATUS*
----------------
  Flw Tmp Prs  ?
r   2 179 499  0
```

```
THROTTLE,%  79.1

****************
*PROCESS STATUS*
----------------
  Flw Tmp Prs  ?
r   2 179 499  0
s  86 359   0  0
o  88 355   0  0
f  88 355 160  0
v  15 358 153  2
1 104 351 140 15
2 104 200  12 27
----------------
FLOW RATE CHECK
 Calculated
 Mr/Mf     0.023
 err,%         0
    Mr      2015
   Mf      88125
 Exptl
    Mr       241
    Mw       135
    Mf     88125
TANK FILL RATE
 ft/hr       3.1
FLOW T CHG.RGE
 Mf,%       41.8
 Mv,%       48.6
DOWNHILL
 Tr        178.5
 To        355.4
 Pw        498.7
SUPERHEAT    2.2
LIQUID PRECOOL
 max Tf    359.4
 max To    357.4
 cal sep T 500.8
 exp Tf    355.4
ELECTRICAL
 volts     468.6
 amps      627.8
 freq       60.5
 PF,%      101.3
 kw        515.4
****************
MACHINE STATUS
----------------
    E BRG T
 163  157  159
```

```
 PF,%       101.3
 kw         515.4
****************
MACHINE STATUS
----------------
    E BRG T
 163  157  159
 166  189  164

    A BRG T
  109      95

    A WDG T
 145  137  138
  38  143  144

   TH BRG F
  1109     449

TRACK ONE!!!!!!!
****************
05/14   13:40:48

RECORDED
# of files   2.0
last #       5.0
run #       39.0


trk1 to 0


PROC. CONSTANTS
 C
    T   6442
ORIFICE DIAMETER
  Liquid    2.50
   Steam    4.00
****************
```

```
**WARNING!!
% of range   1.2
*Change ORFICE*
****************
05 14   12:02:59

MACHINE STATUS
----------------
    E BRG T
```

Note: Data overlaps to show continuity, except for 4th piece; all examples are from the same roll of data.

Figure 2-15. Examples of Thermal Printer Special Displays as Produced by the Final Operating Program

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13 15 0	175	358	353	355	350	16.0	137	157	2	150	157	497	69	2	84	86	15.8	100	83	1	92	520	60.5	47	188
13 15 20	175	358	354	355	350	15.9	139	157	2	151	157	494	65	2	84	86	16.0	100	83	3	81	515	60.3	46	188
13 15 40	175	359	354	354	350	15.3	138	159	2	151	158	496	66	2	86	88	15.6	101	83	3	81	539	60.3	49	188
13 16 0	175	359	354	354	350	15.4	139	158	2	151	158	492	65	2	85	87	15.6	100	83	3	81	518	0.1	47	188
13 16 20	176	359	354	353	350	15.4	139	157	2	151	159	491	65	2	85	88	15.8	100	83	3	80	517	59.9	47	189
13 16 40	176	359	355	353	350	15.1	139	157	2	151	159	491	65	2	86	88	15.6	100	83	3	80	518	60.0	47	188
13 17 0	176	359	355	352	350	15.0	140	158	2	152	159	490	64	2	86	88	15.5	99	83	3	81	521	60.0	48	189
13 17 20	176	359	395	353	350	15.2	139	157	2	152	159	491	66	2	86	88	15.7	99	83	3	79	515	59.9	47	188
13 17 40	176	359	355	353	350	15.1	138	158	2	151	158	491	66	2	85	87	15.4	98	83	2	81	515	60.0	48	188
13 18 0	176	359	355	353	350	15.9	140	157	2	152	159	492	72	2	95	97	16.2	99	83	0	80	517	60.1	46	188
13 18 20	176	359	355	354	350	15.6	139	157	2	152	158	491	65	2	86	88	16.1	97	83	3	90	519	60.0	46	188
13 18 40	176	359	355	354	350	15.7	138	159	2	151	158	494	66	2	84	86	15.8	97	83	2	80	515	60.2	47	188

TIME	Tr	Ts	To	Tf	Tl	Ol	Pl	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	'/h	Trt%	KW	freq	eff%	BrgT
13 19 0	176	359	355	354	350	15.5	138	157	2	151	158	491	64	2	85	87	15.7	100	83	3	82	518	60.1	47	188
13 19 20	176	359	355	354	350	15.4	139	159	2	151	159	489	64	2	84	86	15.4	100	83	3	81	518	59.9	48	188
13 19 40	176	359	355	354	350	15.8	139	158	2	151	159	490	64	2	85	87	16.1	102	83	3	81	518	60.1	46	188
13 20 0	176	359	355	355	351	15.5	140	159	2	152	159	491	63	2	84	86	15.6	104	93	3	80	517	60.0	47	188
13 20 20	176	359	355	355	351	15.7	139	159	2	152	158	493	74	2	84	87	15.8	106	83	-1	91	518	60.2	47	188
13 20 40	177	359	355	355	351	15.7	140	159	2	152	158	490	74	2	86	89	16.1	106	83	-1	81	518	60.1	46	188
13 21 0	177	359	355	355	351	15.[illegible]	140	159	2	152	159	493	64	2	84	86	15.8	107	93	3	81	517	60.1	47	189
13 21 20	177	359	355	355	351	15.5	140	159	2	152	158	492	74	2	85	87	15.8	109	83	-0	80	520	60.2	47	188
13 21 40	177	359	355	355	351	15.3	139	160	2	152	159	494	64	2	95	97	15.4	109	84	3	80	517	60.1	47	189
13 22 1	177	359	355	355	351	15.7	139	157	2	152	158	494	65	2	83	85	15.6	110	93	2	80	517	60.2	47	189
13 22 20	177	359	355	355	351	15.2	140	161	2	153	158	494	65	2	87	89	15.7	110	93	3	80	517	60.2	47	189
13 22 40	177	359	355	355	351	15.6	140	159	2	152	158	496	65	2	86	88	16.0	110	93	3	80	521	60.2	46	188
13 23 0	177	359	355	355	351	15.6	140	159	2	152	159	497	67	2	86	88	15.[illegible]	110	94	2	80	519	60.4	46	189
13 23 20	177	359	355	355	351	15.6	139	159	2	152	159	498	66	2	85	87	15.8	110	83	2	79	519	60.5	47	188
13 23 41	177	359	355	355	351	15.5	140	159	2	152	159	494	64	2	83	[illegible]	15.4	111	84	2	79	518	60.3	48	188
13 24 0	177	359	355	355	351	15.5	141	159	2	153	159	495	65	2	85	87	15.8	111	94	3	78	515	60.5	46	188
13 24 20	177	359	355	355	351	15.6	140	159	3	152	159	497	65	2	84	86	15.7	111	94	2	90	518	60.5	47	188
13 25 0	177	359	355	355	351	15.6	141	159	3	152	160	498	65	2	84	86	15.7	111	94	2	79	518	60.5	47	189
13 25 20	177	359	356	355	351	15.7	140	159	2	152	158	499	65	2	86	87	16.0	112	84	3	79	518	60.5	46	188
13 25 40	177	360	356	355	351	15.5	138	159	2	152	159	499	65	2	95	87	15.6	111	94	3	79	522	60.6	47	189
13 26 0	177	359	356	355	351	15.0	140	160	2	153	160	494	67	2	97	88	15.4	112	94	2	78	518	60.1	47	188
13 26 20	177	359	356	355	351	15.4	141	159	2	153	160	492	65	2	85	86	15.5	112	84	2	79	518	60.2	47	188
13 26 40	177	359	356	355	351	15.2	140	160	2	153	159	490	64	2	86	87	15.5	112	84	3	79	517	59.9	47	188
13 27 0	177	359	356	355	351	15.3	140	160	2	153	160	494	64	2	86	98	15.8	112	94	3	79	515	60.2	46	188
13 27 20	177	359	355	355	351	15.3	140	160	2	153	158	492	65	2	86	87	15.6	112	84	3	78	514	60.1	47	188
13 27 41	177	359	355	355	351	15.3	142	160	2	153	158	491	65	2	84	96	15.3	112	94	2	78	514	60.0	47	188
13 28 0	178	359	355	355	351	15.5	141	159	2	153	159	489	54	2	85	97	15.7	112	84	3	79	516	59.9	47	188
13 28 20	178	359	355	355	351	15.4	140	160	3	152	159	491	66	2	94	96	15.3	112	84	2	80	517	59.9	48	188
13 28 40	178	359	355	355	351	15.6	140	160	2	152	160	491	64	2	86	88	16.0	113	94	3	91	518	60.0	46	188
13 29 0	178	359	355	355	350	15.6	138	159	2	151	159	494	64	2	88	90	16.1	113	94	4	82	523	60.3	46	188
13 29 20	178	359	355	355	350	15.6	138	159	2	151	159	494	65	2	85	87	15.7	113	84	3	83	521	60.2	48	188
13 29 40	178	359	355	355	350	15.5	140	159	2	152	159	493	65	2	87	89	15.9	112	84	3	91	517	60.1	46	188
13 30 0	178	359	355	355	351	15.2	140	160	2	152	158	495	65	2	86	88	15.5	113	84	3	90	519	60.3	47	188
13 30 20	178	359	355	355	351	15.2	140	160	2	152	159	501	67	2	85	87	15.4	113	94	2	79	515	60.7	47	188
13 30 41	178	359	355	355	351	15.3	140	160	2	152	160	497	65	2	85	87	15.4	113	94	3	78	515	60.5	47	188
13 31 0	178	359	355	355	351	15.2	140	159	2	153	158	497	66	2	85	87	15.5	113	84	3	78	515	60.4	47	188

TIME	Tr	Ts	To	Tf	Tl	Ol	Pl	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	'/h	Trt%	KW	freq	eff%	BrgT
13 31 21	178	359	355	355	351	15.2	141	159	2	153	159	496	68	2	86	89	15.6	113	84	2	78	515	60.4	46	188
13 31 40	178	359	356	355	351	15.5	140	160	2	152	159	495	65	2	96	88	15.7	113	94	3	80	518	60.3	47	188
13 32 0	178	359	355	355	351	15.3	140	159	2	152	159	493	66	2	86	88	15.6	113	94	2	80	518	60.2	47	188
13 32 20	178	359	356	355	351	15.1	139	160	2	152	160	497	65	2	87	89	15.9	113	84	3	82	523	60.4	47	188
13 32 40	178	360	356	355	350	15.4	139	159	2	151	159	496	66	2	87	89	15.8	113	84	3	81	524	60.5	47	188
13 33 0	178	359	356	355	350	15.2	139	160	2	152	159	497	67	2	88	90	15.9	113	94	3	93	525	60.4	47	188
13 33 20	178	359	356	355	350	15.2	140	159	2	152	160	501	65	2	97	89	15.8	113	94	3	92	521	60.9	47	189
13 33 40	178	359	355	355	351	15.2	140	160	2	153	159	503	65	2	9[illegible]	89	15.7	114	84	3	79	517	60.9	46	188
13 34 0	178	35[illegible]	356	355	351	15.0	140	160	2	153	160	496	66	2	96	89	15.2	114	94	2	78	514	60.4	47	188
13 34 21	178	359	356	355	351	15.4	140	159	2	153	159	495	69	2	86	89	15.8	114	84	2	77	515	60.4	46	188
13 34 40	178	359	356	355	351	15.4	141	160	2	153	160	498	65	2	85	87	15.5	114	84	3	78	515	60.5	47	188
13 35 1	179	359	356	355	352	15.[illegible]	142	160	2	154	160	496	65	2	85	87	15.5	114	94	3	77	515	60.3	47	188
13 35 20	178	359	356	355	352	14.9	142	162	2	153	160	495	65	2	86	88	15.3	115	94	3	79	518	60.3	47	188
13 35 41	178	360	356	355	351	15.2	140	159	2	152	159	490	66	2	85	97	15.3	115	84	2	79	521	59.8	47	189
13 36 0	178	360	356	355	351	15.6	139	159	3	151	159	492	66	2	86	88	15.9	115	84	3	80	521	60.0	47	189

RECORDED data,run number 38

13 37 40	179	360	356	355	351	14.9	142	160	2	153	159	492	65	2	85	97	15.0	116	84	3	80	514	60.1	48	188
13 38 0	179	359	356	355	351	15.3	141	160	2	152	159	495	67	2	85	87	15.5	115	94	2	79	515	60.4	47	188

Figure 2-16. Example of Impact Printer Operating Log as Produced by the Operating Program: 1978

```
        Log  for  run  15  on  11/13    13:08:23
   Orifice diameter for liquid 2.50, for steam 4.00   TDS= 5000 ppm;Inert gases=    wt% of stm (Proprietary)
                                                                                                                                      T(expander bearings)
   TIME     Tr   Ts   To    Tf    Ti    Q1    Pi   Pf  Tsep  Pv   Ps   Pw   Nw   Nr   Ns   Nf   Nv  Ls  Lw '/h  Trt%  KW freq eff% File     Pi    Pd   PF%  T(alt brgs)  THRin THRf HPJn HPJf LPJn LPJf  ThrBrgForce
 13  0 23  116  363 365.4 363 7 365.2  21.1  136  221   5  217  230  427  95   -1   68   67 19.0  84  37 -13   37  593 60.0 45.1          181  161103.5   55   42   180  164  159  151  151  146  1357   264
 13  9 13  117  364 363.0 363.1 359.9  10.6  160  219   5  216  229  422  94    0   86   86 20.2  83  37  -0   52  673 59.6 46.6          160  153103.2   55   42   190  165  163  155  165  154  1442   305
 13 10 15  117  369 368.3 363.0 359.2  16.3  160  218   5  217  230  423  94    0   97   97 19.5  83  36  -4   55  686 59.6 46.9          160  147103.1   55   42   190  165  164  157  167  156  1487   326
 13 11 16  118  373 372.2 363.1 362.2  12.3  175  219   5  222  233  423  94    1  118  119 17.8  83  36   2   54  693 59.6 46.7          175  154102.7   55   41   191  166  167  156  160  156  1506   319
 13 11 50  118  375 374.2 364.0 361.2  12.5  171  219   5  221  233  426  94    0  122  122 18.0  83  36   3   60  714 59.8 47.3          171  153103.0   55   42   191  166  167  157  160  157  1545   343
 13 12 51  119  376 376.0 369.1 356.3  13.6  161  216   5  220  232  426  95    0  126  126 18.9  83  36   4   73  740 59.9 47.2          161  145103.1   53    /   192  166  168  158  165  157  1597   365
 13 14  3  120  376 376 1 372.9 356.6  13.7  162  217   5  221  232  427  95    0  125  125 18.4  83  36   4   72  750 60.0 47.5          162  143103.1   52   41   192  166  167  158  169  157  1599   337
Fast response log taken at 11/13  13:14:03
 13 15  6  123  376 375.9 375.7 357.3  14.3  162  216   5  221  233  427  95    0  124  124 18.6  83  36   3   70  752 60.1 47.0          162  130103.1   56   43   192  166  160  158  169  157  1623   427
RECORDED data, set number  80,  5 files,last file 0  29  at 11/13  13:16:17
 13 16 33  124  376 376.0 375.5 357.1  14.1  163  217   5  221  233  430  95    0  124  124 18.4  83  36   3   71  752 60.2 47.2          163  143103.2   52   37   192  166  164  159  154  157  1585   334
 13 16 59  125  375 375.5 372.7 357.0  13.8  163  217   4  221  233  429  95   -0  125  124 18.5  83  36   3   71  752 60.2 47.4  30      163  142103.2   49   36   192  166  166  151  163  157  1591   323
Fast response log taken at 11/13  13:17:59
 13 19  1  129  377 376.5 375.6 358.3  14.7  149  216   5  219  231  426  95    0  132  132 19.4  83  36   5  100  785 59.9 47.7          149  132103.9   56   43   192  166  160  159  170  158  1686   405
Fast response log taken at 11/13  13:19:16
RECORDED data, set number  81,  5 files,last file 0  35  at 11/13  13:20:39
Fast response log taken at 11/13  13:20:49
 13 21 12  131  376 376.2 375.9 358.3  14.7  149  215   5  219  231  427  95    0  131  132 19.1  83  37   5  100  703 60.0 47.9          149  130103.0   57   43   193  166  169  159  170  158  1659   300
Fast response log taken at 11/13  13:21:46
 13 24 14  137  376 375.7 375.7 356.0  14.6  161  218   5  222  234  430  95    0  125  125 19.3  84  37   3   73  754 60.1 45.4          161  155103.4   56   44   192  166  160  159  169  158  1575   356
 13 25 56  141  376 375.7 370.9 356.7  13.9  162  218   5  221  233  429  95    0  125  126 18.4  84  37   4   73  755 60.2 47.4          162  142103.0   52   40   192  153  161  159  170  154  1600   325
 13 27 17  145  376 375.9 375.4 356.0  13.9  163  218   5  221  233  428  95    0  125  125 18.2  83  37   3   72  754 60.1 47.2          163  144103.2   57   43   192  166  160  159  170  157  1582   321
 13 29 19  148  376 376.0 375.4 357.1  13.8  163  218   5  221  233  429  95    0  125  125 18.0  84  38   3   71  753 60.2 47.6          163  145103.2   57   43   192  166  160  159  170  158  1575   345
 13 31 20  151  376 376.1 375.6 357.2  13.8  163  218   5  221  233  429  95    0  125  125 18.1  84  38   3   71  753 60.2 47.2          163  146103.2   57   43   192  166  160  159  170  158  1574   250
 13 33 22  154  376 376.1 375.6 356.8  13.9  163  218   5  221  233  429  95    0  125  125 18.2  83  38   3   72  753 60.2 47.3          163  146103.2   57   43   192  166  160  159  170  158  1560   243
 13 35 23  157  376 376.1 375.6 356.5  14.0  161  218   5  221  233  429  95    0  125  125 18.3  84  38   3   73  756 60.2 47.2          161  143103.2   57   44   192  166  160  159  170  158  1571   332
 13 37 25  160  377 376.4 375.6 356.5  13.9  161  218   5  221  233  428  95    0  126  126 18.2  84  39   4   74  756 60.2 47.4          161  143103.2   58   44   192  166  160  159  170  158  1563   330
 13 39 26  163  378 377.0 376.0 356.7  14.0  162  217   5  221  232  428  95    0  125  125 18.2  83  39   3   73  755 60.2 47.4          162  142103.2   58   44   192  166  160  159  170  158  1575   264
   TIME     Tr   Ts   To    Tf    Ti    Q1    Pi   Pf  Tsep  Pv   Ps   Pw   Nw   Nr   Ns   Nf   Nv  Ls  Lw '/h  Trt%  KW freq eff% File     Pi    Pd   PF%  T(alt brgs)  THRin THRf HPJn HPJf LPJn LPJf  ThrBrgForce
 13 41 27  166  379 378.0 377.2 357.0  14.1  163  217   5  221  233  429  95    0  124  124 18.1  84  39   3   72  754 60.2 47.2          163  146103.1   58   44   192  166  160  159  169  158  1566   250
 13 43 29  169  380 380.3 378.3 357.3  14.2  163  217   5  222  233  430  95    0  123  123 18.1  84  39   3   71  754 60.3 47.1          163  149103.1   58   44   192  166  160  159  170  158  1562   300
 13 45 30  172  381 381.3 379.5 357.6  14.2  164  218   5  222  233  428  95    0  122  122 17.0  83  39   2   70  754 60.2 47.5          164  144103.5   59   44   192  166  160  159  170  158  1565   254
 13 47 32  176  382 382.2 380.7 357.0  14.4  164  218   5  222  233  429  95    0  122  122 17.0  83  40   2   70  754 60.2 47.3          164  144103.0   59   44   192  166  160  159  169  157  1555   280
 13 49 33  179  383 382.0 381.7 358.1  14.6  165  218   5  222  234  430  95    0  121  121 17.9  83  40   2   69  754 60.3 47.0          165  146103.0   59   44   192  166  160  159  169  157  1566   280
 13 51 34  183  383 38' 2 382.3 358.2  14.6  165  218   5  223  233  430  95    0  121  121 17.8  84  40   2   69  754 60.3 47.2          165  144103.0   59   45   192  166  160  159  169  157  1563  286
 13 53 36  186  383 383.4 382.6 358.3  14.5  165  218   5  222  234  430  95    0  121  121 17.6  84  40   2   69  754 60.3 47.3          165  147103.0   59   45   192  166  160  159  169  157  1572   264
 13 55 37  189  384 383.9 382.9 358.7  14.6  166  218   5  223  234  431  95    0  120  120 17.6  84  40   2   68  752 60.3 47.2          166  149103.2   59   45   192  166  160  159  169  157  1570   260
 13 57 39  192  384 383.9 383.3 358.7  14.7  166  218   5  223  234  430  95    0  120  120 17.7  83  40   1   67  753 60.3 47.1          166  149103.2   59   44   192  166  160  159  170  157  1575   270
 13 59 40  195  384 384.1 333.4 358.5  14.7  166  218   5  222  234  430  95    0  120  120 17.7  83  40   2   68  753 60.3 47.0          166  145103.3   59   45   192  166  160  159  169  157  1575   269
 14  1 42  198  384 384.4 383.6 358.6  14.0  166  218   5  223  234  430  95    0  120  120 17.7  83  40   1   68  753 60.3 46.9          166  149103.2   60   45   192  166  160  159  169  157  1570   255
 14  3 44  202  385 384.4 383.9 358.7  14.6  166  218   5  222  233  429  95    0  120  120 17.5  83  40   1   67  753 60.3 47.3          166  143103.2   60   45   192  166  160  159  169  157  1582   264
 14  5 45  205  385 384.5 384.0 358.7  14.0  166  218   5  223  234  430  95    0  119  120 17.7  84  41   1   67  754 60.3 47.0          166  149103.2   60   45   192  166  160  159  169  158  1549   240
 14  7 47  208  385 383.9 382.0 358.6  14.4  166  219   4  222  234  430  95    0  119  120 17.4  84  41   1   68  753 60.3 47.7          166  147103.2   57   43   192  166  167  159  169  157  1542   265
 14  9 48  211  383 382.3 381.6 358.7  14.3  166  219   5  223  234  429  95    1  119  120 17.3  84  41   1   67  753 60.3 47.9          166  147103.2   49   38   190  166  160  159  169  143  1553   249
 14 11 50  215  384 383.0 383.2 358.6  15.3  166  218   4  223  234  430  89    0  112  113 17.6  82  41   1   67  753 60.3 48.6          166  150103.3   53   30   192  166  166  158  169  157  1581   259
Fast response log taken at 11/13  14:13:21
 14 15  4  219  384 383.0 383.1 344.6  15.0  155  199   9  208  212  360  89   -0  116  116 16.0  78  41   2   64  727 60.3 46.6          155  151100.5   56   41   192  164  166  159  154  155  1563   253
Fast response log taken at 11/13  14:15:20
 14 17  4  226  385 384.9 384.3 358.0  15.6  166  219   5  222  233  429  95   -0  119  119 17.9  85  41   1   69  756 60.3 46.0  36      166  151103.0   61   46   192  166  160  159  170  158  1634   257
    No good.
Fast response log taken at 11/13  14:17:30
 14 22  0  235  385 373.4 384.5 358.0  14.0  168  219   5  222  233  429  95    9  118  119 17.7  83  41  -2   67  755 60.2 46.0          168  130103.7   -5   -5   192  166  160  159  165   -5  1714   345
Fast response log taken at 11/13  14:23:36
 14 27  7  242  385 384.9 384.3 358.8  14.0  165  219   5  223  234  425  95   -0  119  119 17.4  83  41   1   68  753 50.3 47.3          165  144103.4   62   46   192  166  160  159  169  158  1560   166
 14 32  0  251  385 384.6 384.2 358.3  14.8  165  219   5  222  233  429  95    0  120  120 17.6  83  41   1   60  755 60.3 47.1          165  146103.3   60   46   190  165  168  156  166  155  1550   236
 14 37 45  255  386 385.5 384.2 361.6  14.0  159  202  12  210  216  400  80    0  114  114 16.4  81  40   2   57  713 60.1 46.0          159  150110.1   62   47   189  165  166  157  167  156  1402   229
Fast response log taken at 11/13  14:40:51
 14 42 36  256  400 400.5 399.9 375.6  14.6  207  260   5  275  282  446  90   -0  117  117 17.3  83  42   2   47  801 60.6 44.6          207  179103.0   -1   47   193  168   -5   -5  169   -5  1695   171
```

Figure 2-17. Example of Operating Log as Produced by the Operating Program: 1979 data on tape. A sample of the fast response log is shown in Figure 2-18. An example of data logging sequence can be seen within the two figures. In Figure 2-17, the fast response log was called for at time 13:14:03, and the call was logged. Data logging then switched to the fast response log at 13:14:15, where the system recorded and displayed five rows of process data at four successive intervals of about 11 seconds. Note the steady Mw, Ms, Mf and Mv flow rates, throttle position Trt%, power kW and frequency freq (see Figure 2-18). Shortly after 13:15:06 (see Figure 2-17), instructions were given to the computer to log five samples of data on tape as Set No. 80. This operation was completed at 13:16:17, with the fifth sample being recorded in File No. 29 as logged. By coincidence, this record was followed shortly by an automatic recording of an averaged unnumbered set of data in File No. 30, as can be seen under the File heading. Another similar data inspection and logging sequence began at 13:19:16 with the call for a fast response log. The fast response log began 3 seconds later. The subsequent recording of another set of five files of data as Set No. 81 was completed, with the last File No. 35 recorded at 13:20:39 as shown. Under the urgency of a very severely limited test schedule, the high level of confidence in the data system made it feasible for these three sets of data to represent the total test record for two distinctly different operating conditions at approximately 3/4-MW load as can be seen by comparing the inlet pressure P1 and throttle position Trt% for the three sets. It can be seen that the automatic record in File No. 36 was classified as "No good" by operator notation. Also, a new test condition is indicated as being attained by the last row of data on the page.

An example of the main operating log with start-up and shutdown information for part of Run No. 13, on November 13, 1979, is shown in Figure 2-19. The test objectives of 750 kW and 1000 kW for various inlet conditions were entered by the operator just below the heading. In addition to the run number, date and time, the heading displays the orifice diameters, the dissolved solids content of the water, and the content of impurities in the steam in weight percent (which are used in the calculations). The cumulative values of energy produced, liquid and steam received from the FTF, and waste water returned as of the end of the previous test, are calculated and also automatically displayed in the heading. The data log of Figure 2-19 continues on the second page, where a test shut-down was recorded. The record shows that the fault system monitoring feature of the operating program detected an underspeed condition as the first fault. The fault event triggered the computer to log the voltage of the 43 parameters of the X vector from the last data scan prior to the fault event. In addition, the cumulative values discussed above were automatically calculated and logged along with the time. An added note recorded by the operator indicates that the plant was stopped by a process difficulty associated with the starting of the waste pump. Notes such as this, entered in the operating log, are easier to correlate with the tests than notes entered in notebooks.

The testing at Cerro Prieto, Mexico, was conducted by CFE using the JPL data system and an operating program based on JPL operating programs used in Utah. The same calibration procedures and a and b matrix were used, and all relevant test parameters were assigned to the same J values of computer memory as in Utah.

ORIGINAL PAGE IS
OF POOR QUALITY

TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
11 45 19	97	364	363.7	368.1	364.7	178.9	220	215	227	436	96	0	69	69	17	89	44	33	554	60
11 45 31	97	364	363.9	368.3	364 7	176.7	220	216	227	437	96	0	70	71	17	88	43	35	553	60
11 45 43	97	365	363.7	368.3	364.7	177.7	222	216	227	437	96	0	70	70	16	88	44	33	555	60
11 45 54	97	365	364.1	368.2	364 7	180.7	220	215	227	436	95	0	69	70	17	87	43	35	553	60
Log for run 13 on 11/13 11:52:53																				
Log for run 13 on 11/13 12:18:47																				
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
12 52 49	-71	355	373.5	366.2	361.2	169.9	227	229	235	437	95	-4	77	72	8	86	43	21	264	60
12 53 0	105	365	364.5	354.5	360.2	170.8	228	229	236	433	95	0	73	73	7	84	43	22	262	60
12 53 48	-71	366	366.0	341.9	355.3	160.9	228	228	236	432	95	-0	79	79	8	85	42	23	264	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
12 55 21	108	368	367.4	356.2	360.7	168.6	226	229	236	434	95	0	71	71	7	86	42	21	261	60
12 55 31	108	367	367.2	357.6	361.2	173.3	227	230	237	435	95	0	70	70	7	86	42	19	262	60
12 55 43	109	367	367.0	359.1	361.2	172.6	226	230	236	432	95	0	71	71	7	84	42	21	262	60
12 55 55	-71	355	373.5	366.3	362.2	173.9	227	230	236	435	95	-4	73	69	7	86	41	-11	-2	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
12 57 21	110	366	366.0	364.8	362.2	173.3	226	229	236	437	95	0	68	68	7	82	41	18	265	60
12 57 31	110	366	365.8	365.3	362.2	174.5	226	229	236	435	95	0	68	68	7	84	41	18	265	60
12 57 43	110	366	365.7	365.7	362.7	174.8	228	230	237	434	95	0	67	67	7	83	41	20	264	60
12 57 55	110	366	365.7	366.0	362.7	171.1	228	230	236	437	95	0	67	68	7	83	41	19	264	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 5 12	115	364	363.8	366.9	364.7	179.4	223	220	231	429	95	0	67	67	16	85	38	32	505	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 5 35	115	364	363.7	366.9	364.7	178.2	223	221	231	427	95	0	66	66	16	83	38	34	504	60
13 5 46	115	364	363.7	366.9	363.2	172.3	223	220	229	426	95	0	69	69	16	84	38	36	532	60
13 5 58	115	364	363.7	367.0	362.2	170.8	223	219	230	425	95	0	71	71	17	83	38	37	548	60
13 6 10	115	364	363.6	367.0	360.7	163.1	221	219	230	422	94	0	74	74	18	83	38	45	586	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 14 15	121	376	375.9	369.0	356.8	163.7	220	222	233	429	95	0	125	125	18	84	36	71	751	60
13 14 25	122	376	376.2	375.5	356.8	163.7	218	221	233	430	95	0	123	124	18	83	36	72	751	60
13 14 37	122	376	376.1	374.0	357.3	163.4	220	220	233	430	95	0	124	124	17	83	36	71	752	60
13 14 49	122	376	376.0	375.7	357.3	161.8	217	222	233	429	95	0	124	124	18	82	36	71	752	60
13 15 0	122	376	375.9	375.6	357.3	162.4	217	221	232	428	95	0	124	124	18	84	36	72	751	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 18 2	127	376	375.5	375.6	352.3	150.4	215	220	231	427	95	0	132	132	19	82	37	100	788	60
13 18 12	127	376	375.9	375.7	351.3	151.3	215	219	231	427	95	0	132	132	19	82	36	100	786	60
13 18 22	128	377	376.1	375.7	350.8	149.1	215	220	231	427	95	0	132	132	19	83	37	100	786	60
13 18 34	128	377	376.5	375.6	350.3	150.4	216	219	231	428	95	0	131	132	18	84	36	100	786	60
13 18 45	128	377	376.6	375.6	350.3	148.6	215	218	231	424	95	0	131	131	19	83	36	100	784	60
13 18 55	128	377	376 5	375.6	350.3	150.4	216	218	231	429	95	0	133	133	19	84	36	100	783	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 19 19	129	377	376.4	375.4	350.3	150.4	216	218	231	427	95	0	131	132	19	83	36	100	787	60
13 19 31	129	377	376.4	375.4	350.3	147.9	217	218	231	427	95	0	132	132	18	85	36	100	783	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 20 54	132	376	376.2	376.0	350.3	148.8	215	218	231	427	95	0	132	133	19	84	37	100	782	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
13 21 46	133	376	375.9	375.8	352.8	157.8	216	221	231	425	94	0	127	127	20	83	37	78	761	60
13 21 57	134	376	376.0	375.8	354.3	159.0	218	220	231	431	95	0	126	127	17	83	37	76	756	60
13 22 7	134	376	376.1	366.3	355.3	159.6	216	221	231	428	95	0	126	126	18	83	37	75	754	60
13 22 19	135	376	375.9	375.7	355.8	161.5	217	221	233	430	95	0	125	125	19	84	37	73	755	60
13 22 31	135	376	374.1	370.1	356 3	161.8	218	220	233	427	95	1	125	126	18	84	37	74	753	60
13 22 42	135	376	375.7	375.8	356.3	161.5	218	221	232	428	95	0	125	125	18	83	37	73	754	60
13 22 52	136	376	375.6	375 8	356.3	162.1	217	222	233	427	95	0	125	125	18	84	37	73	753	60
13 23 4	137	376	375.7	375.8	356.8	160.6	221	221	233	429	95	0	124	124	18	85	37	72	755	60
TIME	Tr	Ts	To	Tf	Ti	Pi	Pf	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	Trt%	KW	freq
14 13 25	219	385	384.9	384.1	358 3	164.6	218	223	233	429	95	-0	121	121	17	83	41	67	755	60
14 13 36	219	385	385.1	384.0	358 8	165.8	218	223	233	429	95	-0	119	119	18	83	41	68	754	60
14 13 46	220	385	384.9	384.0	358.8	165.5	219	223	233	429	95	-0	120	120	18	83	41	66	754	60
14 13 58	220	385	373 4	380.9	358 8	165.2	218	223	234	431	95	9	111	119	17	84	41	67	754	60
14 14 10	221	385	384.8	384.2	358.8	164.9	220	223	234	433	95	0	121	121	17	83	41	67	756	60
14 14 21	220	385	383.6	384.3	358.8	164.3	219	222	234	432	96	1	119	120	18	83	41	68	753	60
14 14 31	220	385	384.9	384 3	358.8	165.8	219	223	234	429	95	-0	119	119	18	83	41	67	755	60
14 14 43	220	385	384.9	384 3	358.3	168.0	218	223	234	430	95	-0	118	118	17	83	41	68	753	60
14 14 55	221	385	384 9	384.3	359 3	165 2	218	223	234	430	95	-0	120	120	18	84	41	68	753	60

Figure 2-18. Example of Fast Log as Produced by the Operating Program: 1979

Log for run 13 on 11/13 07:52:54

Orifice diameter for liquid 2.50, for steam 4.00 TDS= 5000 ppm;Inert gasses= wt% of stm (Proprietary)

At startup the cumulative power is 19 90 mw-hr, liquid from separat.. is 6.155 million pounds; steam from separator is 0.296 million pounds,returned waste liquid is 5.311 million pounds.

Test objectives include 750 kW and 1000 kW for various Qi and Pi.

Data logging commenced at 11/13 07:55:14

TIME	Tr	Ts	To	Tf	Ti	Qi	Pi	Pf	Tsep	Pe	Ps	Pw	Hw	Hr	Hs	Hf	Hv	Ls	Lw	'/h	TrtZ	KW	freq	effZ	File	Pi	Pd PfZ	T(alt	brgs)	THRn	THRf	HPJn	HPJf	LPJn	LPJf	ThrBrg	Force
8 22 7	139	373	375.6	200.1	199.6	0.0	12	215	4	210	221	211	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	400000	20	20	128	133	138	132	107	106	242	35
8 25 30	139	363	367.3	325.7	199.0	12.0	12	215	4	210	220	212	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	400000	20	20	126	133	140	134	109	10?	240	33
8 27 15	139	350	361.2	340.3	199.0	14.3	12	215	4	210	221	212	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	400000	20	20	128	133	140	134	109	102	240	33
8 28 17	139	353	356.5	347.6	199.0	15.1	12	215	4	210	221	211	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	300000	20	20	128	132	141	134	109	102	241	32
8 28 47	139	351	354.5	350.0	199.0	15.3	12	215	4	210	221	212	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	600000	20	20	128	132	141	134	109	102	242	31
8 29 5	139	350	353.5	351.1	199.0	15.5	12	215	4	210	220	211	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	700000	20	20	128	132	141	134	109	102	242	32
8 29 53	139	347	350.3	354.7	199.0	15.9	12	214	4	210	220	211	-0	-0	0	0	0.0	99	36	0	-2	0	55.000000			12	900000	20	20	128	132	141	134	109	102	241	31
8 30 54	139	345	345.9	358.2	199.0	16.2	12	214	4	210	220	211	-0	-0	0	0	0.0	98	37	0	-2	0	55.000000			12	500000	20	20	128	132	141	134	109	102	239	31
8 32 55	138	335	336.7	362.7	199.0	16.7	12	213	4	210	220	211	-0	-0	0	0	0.0	99	37	0	-2	0	55.000000			12	-100000	21	20	128	132	141	135	109	102	106	29
8 34 56	138	326	327.6	365.4	199.3	17.0	12	213	4	209	220	211	-0	-0	0	0	0.0	98	37	0	-2	0	55.000000			12	-600000	21	20	128	132	141	135	109	102	231	29
8 36 58	138	310	319.9	367.1	199.3	17.2	12	213	4	209	220	210	-0	-0	0	0	0.0	98	37	0	-2	0	55.000000			12	-300000	21	20	128	132	142	135	109	102	240	27
8 42 0	138	300	301.4	369.0	199.2	17.5	12	213	4	209	220	210	-0	-0	0	0	0.0	99	37	0	-2	0	55.000000			12	200000	21	20	128	132	142	136	109	102	241	25
8 47 2	138	291	289.3	368.5	199.2	17.3	12	213	4	209	219	210	-0	0	0	0	0.0	99	38	0	-2	0	55.000000			12	300000	21	20	128	132	143	137	109	102	239	24
8 52 3	138	288	285.9	366.2	199.3	17.3	12	213	4	209	219	210	-0	0	0	0	0.0	98	38	0	-2	0	55.000000			12	300000	22	20	128	132	144	137	109	103	238	21
8 52 56	137	288	286.0	364.0	199.3	17.0	12	213	4	209	219	210	-0	0	0	0	0.0	99	38	0	-2	0	55.000000		25	12	300000	22	20	128	132	144	138	109	103	236	21
8 57 58	137	288	286.5	360.1	199.2	16.5	12	212	4	209	219	210	-0	0	0	0	0.0	99	38	0	-2	0	55.000000			12	300000	22	21	129	133	145	138	110	103	235	19
9 2 59	137	287	287.7	356.7	199.2	16.1	12	212	4	208	218	209	-0	-0	1	1	0.0	98	38	1	-2	0	55.000000			12	300000	22	21	127	133	146	139	111	104	236	18
9 8 1	137	285	288.5	353.6	199.2	15.8	12	212	4	208	218	209	-0	-0	0	0	0.0	98	38	0	-2	0	55.000000			12	300000	22	21	129	133	146	140	112	106	235	16
9 13 2	137	283	287.9	352.1	199.1	15.6	12	211	4	208	218	208	-0	-0	0	0	0.0	98	38	0	-2	0	55.000000			12	200000	23	21	130	134	147	140	113	107	233	14
9 18 3	136	280	286.7	350.0	199.2	15.5	12	211	4	207	217	208	-0	-1	14	13	0.0	99	38	4	-2	0	55.000000			12	200000	23	21	130	134	148	141	114	109	232	13
9 21 10	136	279	286.1	350.2	198.9	15.4	12	211	4	207	217	208	-0	-1	14	14	0.0	99	38	5	-2	0	55.000000			12	200000	23	21	131	134	149	142	115	109	234	12
9 26 11	136	276	284.5	348.5	198.8	15.3	12	211	4	207	217	208	-0	-1	14	13	0.0	98	36	4	-2	0	55.000000			12	200000	23	21	131	135	150	142	116	111	232	10
TIME	Tr	Ts	To	Tf	Ti	Qi	Pi	Pf	Tsep	Pe	Ps	Pw	Hw	Hr	Hs	Hf	Hv	Ls	Lw	'/h	TrtZ	KW	freq	effZ	File	Pi	Pd PfZ	T(alt	brgs)	THRn	THRf	HPJn	HPJf	LPJn	LPJf	ThrBrg	Force
9 31 12	135	274	283.0	346.7	198.6	15.1	12	210	4	207	217	208	-0	-1	13	12	0.0	99	38	4	-2	0	55.000000			12	200000	24	22	132	136	151	143	110	112	232	9
9 32 13	135	274	282.0	346.4	198.5	15.0	12	210	4	207	217	207	-0	-1	13	12	0.0	99	38	4	-2	0	55.000000			12	200000	24	22	132	136	151	143	110	113	230	9
9 33 14	135	272	283.3	352.1	198.5	15.6	12	210	4	207	217	208	-0	-1	13	12	0.0	99	38	4	-2	0	55.000000			12	200000	24	22	132	136	151	144	110	113	230	9
9 34 15	135	271	280.0	355.0	197.4	15.9	12	211	4	207	217	208	-0	-1	12	12	0.0	98	38	4	-2	0	55.000000			12	300000	24	22	132	136	151	144	110	113	229	9
9 35 16	135	269	275.9	355.6	196.6	16.0	12	211	4	207	217	208	-0	-1	13	12	0.0	98	38	4	-2	0	55.000000			12	300000	24	22	127	134	140	141	117	112	228	9
9 36 17	135	267	275.5	355.9	196.8	16.0	12	211	4	207	217	208	-0	-1	12	11	0.0	98	38	4	-2	0	55.000000			12	300000	24	22	123	131	142	136	113	108	224	8
9 37 18	135	265	274.7	356.1	197.3	16.0	12	211	4	207	192	208	-0	-1	9	9	0.0	135	38	3	-2	0	55.000000			12	300000	24	22	124	131	144	137	113	109	225	8
9 38 19	135	264	273.0	356.1	197.5	16.1	12	210	4	207	209	208	-0	-1	13	12	0.0	140	38	4	-2	0	55.000000			12	300000	24	22	125	131	145	138	115	110	226	8
9 39 20	135	264	271.5	355.0	197.7	16.3	12	210	4	207	206	208	-0	-0	7	7	0.0	142	38	2	-2	0	55.000000			12	200000	24	22	126	132	146	139	116	111	229	8
9 40 22	135	262	270.7	355.5	197.0	16.0	12	210	4	207	206	208	-0	-1	14	13	0.0	142	38	4	-2	0	55.000000			12	200000	24	22	126	132	146	140	116	112	227	7
9 41 23	135	261	271.3	355.3	197.0	16.0	12	210	4	207	203	208	-0	-1	15	14	0.0	141	38	5	-2	0	55.000000			12	300000	24	22	127	132	147	140	117	112	227	7
9 42 24	135	262	270.9	355.0	197.0	15.9	12	211	4	207	212	208	-0	-1	15	14	0.0	140	38	5	-2	0	55.000000			12	300000	24	22	127	132	14	140	117	113	225	7
9 43 25	135	262	270.5	354.6	197.0	15.9	12	210	4	207	216	207	-0	-1	15	14	0.0	94	38	5	-2	0	55.000000			12	300000	24	22	127	132	147	141	118	113	227	7
9 44 26	134	262	271.0	354.2	197.0	15.9	12	210	4	207	217	208	-0	-1	11	11	0.0	87	38	4	-2	0	55.000000			12	200000	24	22	128	133	140	141	110	114	224	7
9 45 27	134	262	271.2	353.7	197.8	15.0	12	211	4	207	216	208	-0	-1	15	14	0.0	87	38	5	-2	0	55.000000			12	200000	24	22	128	133	140	141	119	114	228	7
9 46 28	134	262	271.4	353.3	197.0	15.0	12	211	4	207	216	208	-0	-1	12	11	0.0	87	38	4	-2	0	55.000000			12	300000	24	22	128	133	140	142	119	115	226	7
9 47 29	134	262	271.5	352.9	197.0	15.7	12	211	4	207	216	207	-0	-1	14	13	0.0	97	38	4	-2	0	55.000000			12	300000	25	22	128	133	140	142	119	115	225	7
9 48 30	134	262	271.6	352.6	197.0	15.7	12	211	4	207	216	208	-0	-1	15	14	0.0	87	38	5	-2	0	55.000000			12	300000	25	22	128	133	149	142	120	115	226	7
9 49 31	134	262	271.7	352.2	197.0	15.6	12	211	4	207	216	207	-0	-1	14	13	0.0	88	38	4	-2	0	55.000000			12	300000	25	22	128	133	149	142	120	116	226	7
9 50 33	134	258	263.3	351.0	198.2	15.6	12	210	4	207	216	207	-0	-1	19	18	0.0	87	38	6	-2	0	55.000000			12	200000	25	22	129	133	149	143	121	116	225	7
Fast response log taken at 11/13 09:50:33																																					
9 51 34	134	258	258.7	348.1	197.8	15.3	12	210	4	207	216	207	-0	-0	20	20	0.0	87	38	6	-2	0	55.000000			12	200000	25	22	129	134	149	143	121	116	223	5
Fast response log taken at 11/13 09:52:18																																					
9 52 57	134	255	248.0	345.4	198.3	14.9	12	209	4	206	215	207	-0	0	0	0	0.0	87	39	0	-2	0	55.000000		26	12	200000	25	22	129	134	150	143	121	117	221	7
9 53 58	134	259	249.2	345.3	198.3	14.9	12	210	4	206	216	207	-0	1	9	9	0.0	87	39	3	-2	0	55.000000			12	200000	25	22	129	134	150	143	122	117	222	6
Second Teflon carrier replaced.																																					
9 55 0	134	265	249.6	345.1	196.0	14.9	12	210	4	206	216	207	-0	1	10	11	0.0	87	39	3	-2	0	55.000000			12	200000	25	22	129	134	150	144	122	117	222	7
9 56 2	134	270	250.0	344.6	194.3	14.8	12	210	4	207	216	207	-0	2	10	12	0.0	87	39	3	-2	0	55.000000			12	200000	25	22	129	134	150	144	122	118	221	6
9 57 3	134	273	250.3	344.0	192.2	14.8	12	210	4	208	216	207	-0	2	0	10	0.0	88	39	3	-2	0	55.000000			12	200000	25	22	130	134	150	144	122	118	219	6

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OF POOR QUALITY

Figure 2-19. Example of Operating Log with Test Start-up and Shutdown: 1979

Log for run 15 on 11/15 09:50:05
Orifice diameter for liquid 2.50, for steam 4.00 TDS= 5000 ppm;Inert gasses= wt% of stm (Proprietary)

TIME	Tr	Ts	Tc	Tf	Tl	Q1	Pl	Pf	Tsep	Pe	Ps	Pu	Nu	V	Ns	Nf	Nn	Ls	Lu	'/h	Trt%	KW	Freq eff% File
9 50 5	134	275	250.0	343.4	190.1	14.7	12	210	4	200	216	207	-0	1	3	4	0.0	87	39	1	17	0	55.000000
9 59 6	134	276	251 0	342.0	186.6	47.9	15	210	3	207	216	207	-0	1	5	6	3.7	87	39	2	93	0	55.0223.5
10 0 0	134	277	252 6	340 6	245.3	63.7	31	210	5	206	215	206	-0	0	1	2	2.3	87	39	1	130	0	55.0 85.1
10 1 10	134	271	262.9	336.3	285.2	21 3	71	200	6	205	214	205	-0	1	23	25	5 4	88	39	7	42	2	60.3 16.0
10 2 11	134	266	261.7	330 4	315.0	24.2	93	207	6	205	2'4	205	-0	1	20	20	6.1	86	39	6	16	4	60.3 14 3
10 3 13	134	261	259.7	323 3	282.0	30.4	50	209	5	200	215	206	-0	0	12	12	4 2	85	39	4	13	-1	55.2 26.4
10 4 14	134	261	~0.9	321 7	225.6	23.4	15	210	6	210	216	207	-0	0	8	8	1.2	86	39	1	55	-0	55.0423.3
10 5 16	134	266	250.0	321.3	224.7	20.7	12	211	4	210	216	207	-0	0	3	3	0.3	88	39	1	79	-0	55.000000
10 6 18	122	273	258.6	320.9	249.2	85.9	31	209	3	207	214	206	-0	0	1	1	4.0	89	39	0	99	-1	56.2 49.9
10 7 20	133	285	265.1	312 9	312.9	22.2	99	207	4	205	214	205	-0	3	18	20	6.1	87	39	5	19	3	60.9 14.4
10 8 22	133	279	274.1	304.1	323 6	19.0	105	200	5	206	214	205	-2	1	21	22	6.2	86	39	7	12	10	61.0 16.4
10 9 24	133	290	272.5	293.2	327.2	17.1	107	200	6	206	214	205	-1	0	20	24	6.2	87	39	7	13	11	60.9 17.1
10 10 25	133	312	293.4	285.5	321.7	0.1	100	207	6	206	214	205	-0	0	36	40	5.5	86	39	11	16	12	60.0 10.7
10 11 27	133	331	317.6	272.9	317.6	3.9	97	207	6	207	214	205	-0	4	47	50	5.1	86	39	15	17	12	60.0 21.2
10 12 29	133	349	342.0	262.4	317.6	1.1	99	206	6	206	214	205	-0	2	59	61	5.2	86	'0	20	15	12	60.0 22.0
10 13 31	133	356	354.3	264.6	320.3	0.6	106	206	6	206	214	205	-0	1	61	61	5.1		40	20	12	12	60.9 22.3
10 14 32	133	357	357.2	283.1	322.4	0.4	106	206	5	207	215	?05	-0	0	61	61	3.6	86	41	20	12	11	60.9 23.6
10 15 34	133	357	357 2	318.9	330.0	-0.9	129	207	6	200	215	206	-0	0	55	55	1.9	86	42	17	0	12	60.9 26.0
10 16 36	133	355	356 1	334.4	336.3	4.1	120	207	6	207	215	205	-0	-0	52	52	2.6	87	42	16	16	75	60.6 30.3
10 17 38	133	355	354.0	347.5	330.7	14.7	126	206	6	204	212	203	-0	-0	47	47	7.9	89	43	15	24	191	60.5 40.0
10 18 40	133	352	353.5	353.1	340.4	17.6	129	205	6	203	212	203	-0	-0	45	45	9.1	87	43	14	25	220	60.6 40.0
10 19 41	132	350	350.0	354.9	342.0	10.0	132	205	6	204	212	203	-0	-0	45	44	9.2	87	44	14	24	222	60.5 40.0
10 20 43	133	349	340.9	355.6	349.?	15.7	151	206	5	205	213	203	-0	-0	41	41	7.0	87	44	13	15	155	60.0 32.9

TIME	Pl	Pd PT%	T(alt brgs)		T(expander bearings) THBn	THBf	HPJn	HPJf	LPJn	LPJf	ThrBrgForce	
9 50 5	12	200000	25	22	130	134	146	140	120	116	219	6
9 59 6	15	500000	25	22	130	134	144	139	119	115	237	5
10 0 0	31	2100000	25	23	137	123	127	121	112	104	331	7
10 1 10	71	61 55.1	26	23	146	122	136	123	125	112	396	7
10 2 11	93	70 44.5	26	24	150	126	141	127	132	119	439	8
10 3 13	50	40-10.9	27	25	140	123	142	127	134	121	370	7
10 4 14	15	0-55.0	27	24	117	113	132	121	129	117	266	6
10 5 16	12	600000	24	21	111	105	127	119	125	109	230	5
10 6 18	31	2000000	24	21	140	114	131	110	126	110	345	2
10 7 20	99	80 39.2	25	20	154	130	144	121	130	123	433	7
10 8 22	105	92 59.3	27	24	157	133	145	131	140	120	465	5
10 9 24	107	94 61.1	20	26	156	133	1'	130	139	128	476	8
10 10 25	100	84 60.5	30	27	159	136	148	134	143	130	495	8
10 11 27	97	81 59.0	31	28	160	137	149	135	144	130	503	9
10 12 29	99	86 59.0	32	28	160	130	150	136	145	131	526	9
10 13 31	106	101 59.9	33	28	162	139	151	137	143	132	544	9
10 14 32	106	94 57.9	34	29	162	140	152	130	146	133	536	9
10 15 34	129	114 59.0	34	29	164	141	152	130	147	134	564	11
10 16 36	120	109100.9	35	29	165	142	152	139	140	134	689	12
10 17 38	126	110102.0	35	30	169	146	153	141	151	138	729	26
10 18 40	129	111102.3	36	30	171	140	153	142	152	140	791	45
10 19 41	132	117102.5	35	31	169	149	153	142	153	140	814	61
10 20 43	151	123 90.6	37	31	170	140	153	142	152	140	824	63

U..Spd;

System operation aborted by switch for

Values of X vector are:

1	0.3595 2	0.3690 3	0.3965 4	0.2025 5	0.1770 6	0.0470 7	0.3760
8	0.5265 9	0.1945 10	0.1900 11	0.1970 12	0.2355 13	0.3875 14	-0.0005
15000000000000 16		0.6630 17	0.4500 18	0.1490 19	0.1355 20	0.1405 21	0.1360
22	0.1450 23	1515 24	0.0560 25	0.0590 26	0.0590 27	0.2060 28	0.2040
29	0.3350 30	[illegible] 31	0.0115 32	-1.6200 33	0.0015 34	0.1395 35	-0.1740
36	0.0410 37	[illegible] 38	0.0005 39	0.0490 40	-0.0000 41	-0.0490 42	0.2510
43	62.9844						

At shutdown the cumulative power is 19.92 mw-h ; liquid from separator is 6.170 million pounds; steam from separator is 0.290 million pounds; returned waste liquid is 5.31. million pounds. This data recorded at 11/13 10:20:53

Plant stopped upon starting pump.

Log for run 15 on 11/15 10:24:00
Orifice diameter for liquid 2.50, for steam 4.00 TDS= 5000 ppm;Inert gasses= 7.0 wt% of stm
At startup the cumulative power is 19.92 mw-hr; liquid from separator is 6.170 million pounds; steam from separator is 0.290 million pounds;returned waste liquid is 5.310 million pounds.

Figure 2-19. (Cont'd)

This made the Mexico test data amenable for analysis by the JPL analysis programs.

Sample data were recorded automatically on cassette by the operating program and by operator command in a manner similar to that used in Utah. In addition, a supplemental record of 1980 test data was logged on cassette by JPL with the second computer which was connected to the primary, or operating computer. This was done with the gracious concurrence and cooperation of CFE test engineers using program additions prepared by Wahl Co. for JPL. It is these 1980 Mexico data, logged by JPL, in sets similar to the Utah data, which are included in this report. The logging of data by CFE operator command and by JPL was done in quick succession under the same test conditions so that both organizations recorded steady-state data which was essentially identical. The data processing by JPL included instrument corrections where necessary. The reporting of the 1980 data logging, analysis and results are included here to demonstrate the extended utility of data management and analysis capability which the JPL data system makes available to the IEA Programme. This includes the concomitant provision for comparative analysis of test data from testing at all sites where the JPL data system is used. (In a meeting June 5 and 6, 1980, in Mexicali, Mexico, of the Executive Committee which governs the IEA HSE Test and Demonstration Programme, all members agreed that JPL should perform a comparative analysis of the test results from all of the test sites at the completion of the tests. The JPL representative expressed interest in performing such an analysis. Using the 1980 Mexico data, this report demonstrates that JPL can perform the analysis using analysis programs and techniques already developed, providing the data are properly logged. It implies that the other test organizations can also do so.)

F. DATA VAN

The Data Van, a thermally-insulated trailer 8-feet wide and 27-feet long, with a subfloor, a hanging ceiling and full headroom for most of its length, was made available to the Project by NASA. The Data Van was outfitted to provide a suitable environment and workspace for power supplies, signal conditioning equipment, computers, printers and interfacing equipment of the data system, and for panel instruments and controls for the power plant (see Figures 2-12 and 2-13). Calibration equipment for pressure and temperature devices was housed in the Data Van, which also provided table space for writing and for calibration work. The Data Van served as the process control center, a field office and a meeting place. A complete library of equipment manuals and drawings was normally maintained in the Data Van, along with office supplies and minor instrumentation maintenance equipment and supplies. Temperature control provided by a window-type air conditioner installed in the forward bulkhead often made the Data Van the only comfortable personnel shelter available. Positive pressurization by single-pass airflow of 50 cfm through activated carbon was provided to ensure against corrosion of electronic equipment by hydrogen sulfide which tends to be ubiquitous at geothermal sites. Many Data Van details are shown in JPL Drawing

No. T-92-93,[2] Van #9137 Modification. The placement of the electronics rack and the size of the plywood computer table, as shown in the drawing, were modified in the field in preparation for 1979 tests in order to make room for a second printer.

G. TEST ARRAY

The JPL strategy of testing the HSE at various sites entailed integrating the expander into a test array which can be moved in pieces and assembled in a functionally reproducible arrangement at the site. The array consists of the HSE power plant, the load bank to provide a variable electrical load to the power plant, and the data and control van (Data Van) which housed instrumentation equipment interfaced through a multiplexer to a computer and printer for data reduction and display. Junction terminals were installed in junction boxes on the power plant to permit the reproducible connection of the load bank and the Data Van to the power plant. At the test site, the power plant was positioned for connection to the process piping, and process instrument wires were connected to the appropriate terminals in the junction boxes. The load bank and the Data Van were positioned at the test site for connection to the power plant in locations compatible with site conditions such as preferred functional layout, prevailing wind, and constraints such as cable lengths imposed by the interconnecting hardware. The test array is represented pictorially in Figure 2-20. The power plant was connected to the load bank with approximately 55-foot lengths of 500 MCM cable. These cables were cut to equal lengths to help ensure equal loads on all three phases of the alternator. The cables were supported in a cable tray which could be assembled in nine different configurations, all of the correct length so that the load bank could be placed in a semicircle around the end of the power system generator. (For details see JPL Drawing No. ED07320A0 1, Geothermal HSE Support Systems Site Plan and Details.) Views of the cable tray installation are shown in Figures 2-21 and 2-22. Cable tray parts for optional assemblies are shown in Figure 2-23. The three junction boxes on the power plant, where power, control and all instrumentation wires to the Data Van were connected, can be seen in Figure 1-1 in front of the alternator and to the right of the lower part of the instrument panel. The instrument lines from the junction boxes to the Data Van are about 150 feet in length, allowing considerable choice in placement of the Data Van. At the Utah test site, these instrument lines were placed in a wooden channel along the cable tray (see Figures 2-21 and 2-22). Excess instrument cable was coiled within the Data Van.

The Data Van contains controls and instruments for frequency, voltage, normal stop and emergency stop, which duplicate controls and instruments on the

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[2] All JPL Drawings referred to in this Final Report are located in "JPL Test Support Equipment for HSE Power Plant in Utah," Reference Drawings (Ref. 2).

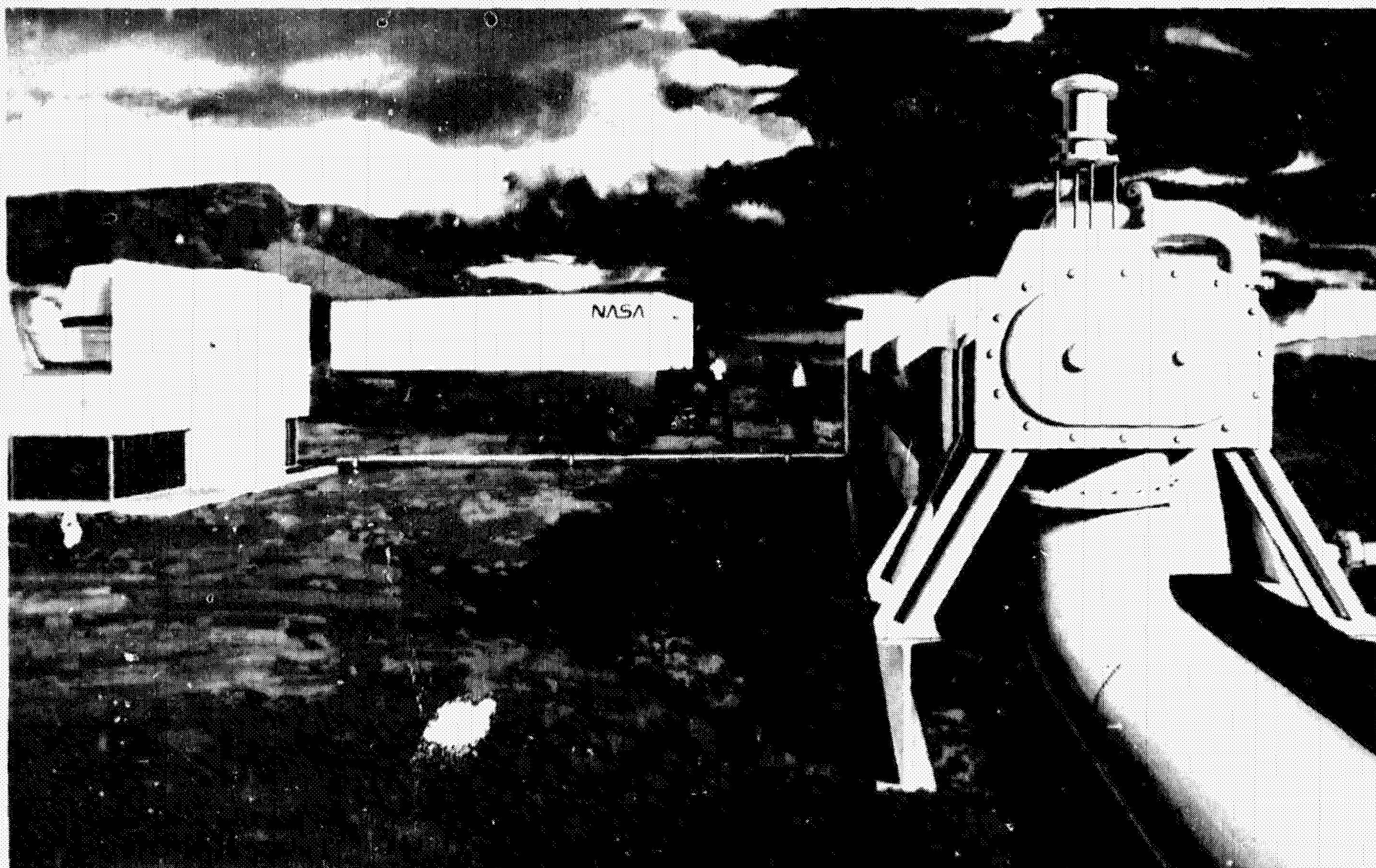

Figure 2-20. Test Array - HSE Power Plant, Load Bank, and Data Van

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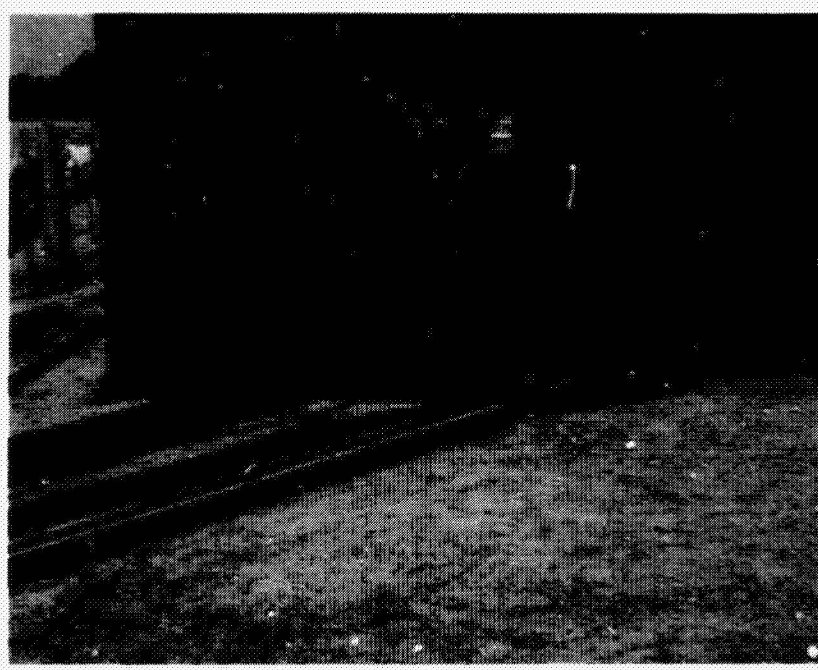

Figure 2-21. Cable Tray Supporting Power Cables Can Be Seen Leaving Building Sheltering HSE Power Plant; Instrument Lines are Contained in Wooden Channel Placed Along Cable Tray

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Figure 2-22. View of Cable Tray between Power Plant Building and Load Bank; Smaller Power Cables Can Be Seen at Right in Cable Tray

Figure 2-23. Cable Tray Parts for Optional Assemblies

power plant. The plant also provides power to the Data Van for lights and air conditioning. These power and control lines were kept separate from the instrument lines on the way to the Data Van. They were supported above the instrument lines either in the cable tray or suspended (Figures 2-22, 2-24 and 2-25). Excess power and control lines were coiled below the Data Van.

The junction boxes referred to above (see Figure 1-1) are shown open in Figures 2-26 and 2-27. The power and control-related lines from the Data Van for instrumentation power, lights, air conditioning, voltage and frequency controls, stop controls, and general service power were connected in the left terminal box EC. The signal wires from the computer for monitoring power plant shutdown functions (i.e., underspeed, overspeed, vibration, low oil pressure, high oil temperature, etc.) were connected in the center box EA. This allowed the computer to identify which function was the cause of automatic shutdown if automatic shutdown occurred. The connections for instrument wires relating to the power plant status (i.e., bearing temperatures and loads, throttle position and alternator bearing and winding temperatures) were located in terminal box EB on the right. Also, all of the process instrumentation lines for fluid flow rates, pressures and temperatures were connected in this terminal box on the way to the computer (the vortex-shedding flow meters were an exception).

During operation of the power plant, the entire electrical power needs of the Data Van were normally supplied by the power system. Power was also supplied to an electrical service panel for general utility loads such as housing, shop, or office trailers which were installed for test support. This utility power panel is shown in Figure 2-28 and is described in JPL Drawing No. D0736A-1.

A 15-kW auxiliary engine generator is also shown in Figure 2-28. This generator provided 115/208 Vac three-phase, 60-Hertz power for the test site in 1979 during periods of test preparations. It replaced an old single-phase diesel power generator which failed and was in turn replaced by another diesel power generator when the engine generator shown in the figure failed. A 10-kW generator, providing 120/240 Vac, 60-Hertz power would have been preferable but was not readily available.

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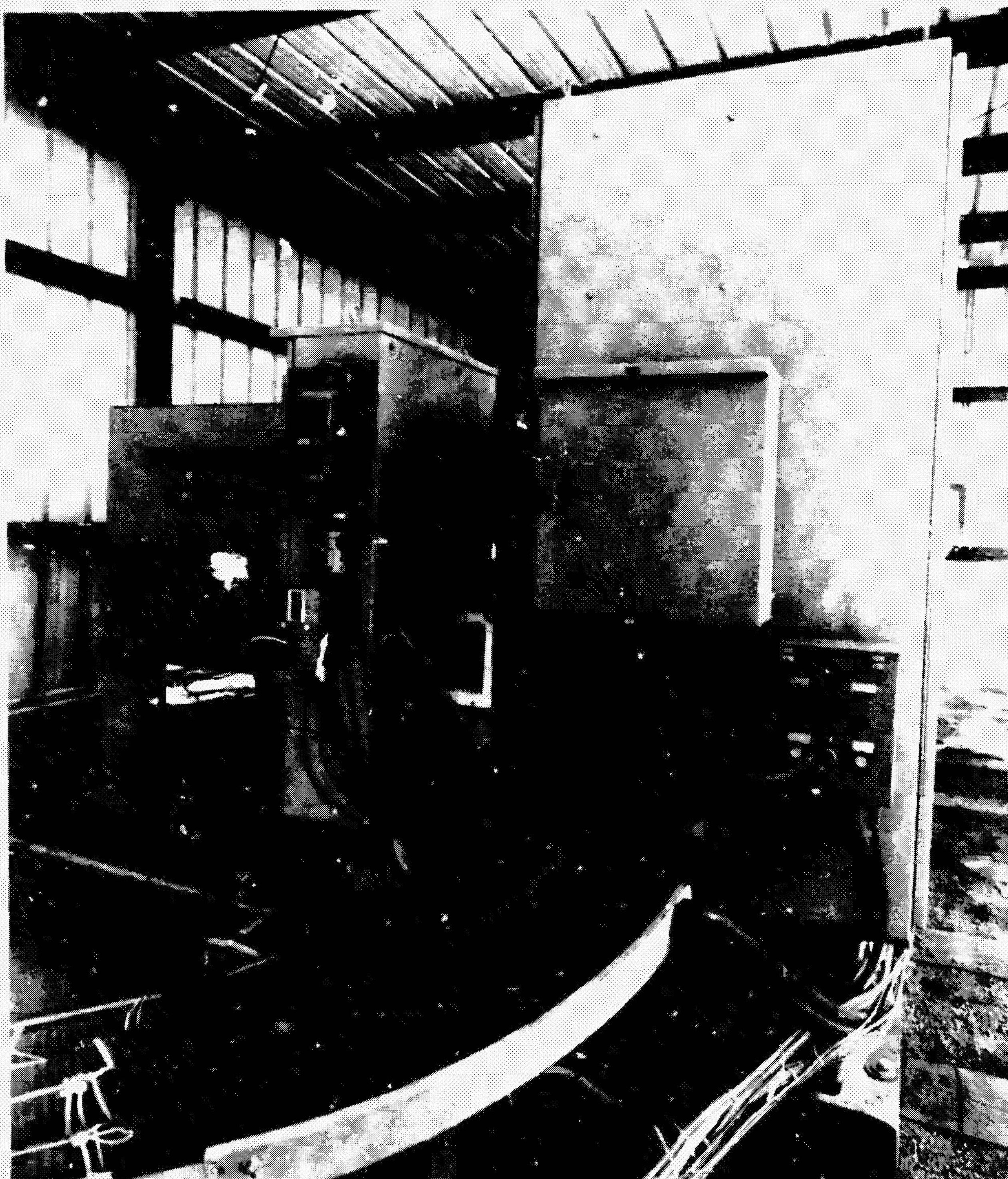

Figure 2-24. End view of Power Plant showing Cable Tray supporting Power Cables; Instrument Lines Lie Beside Tray

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Figure 2-25. Test Array showing Cable Paths and Auxilliary Generators

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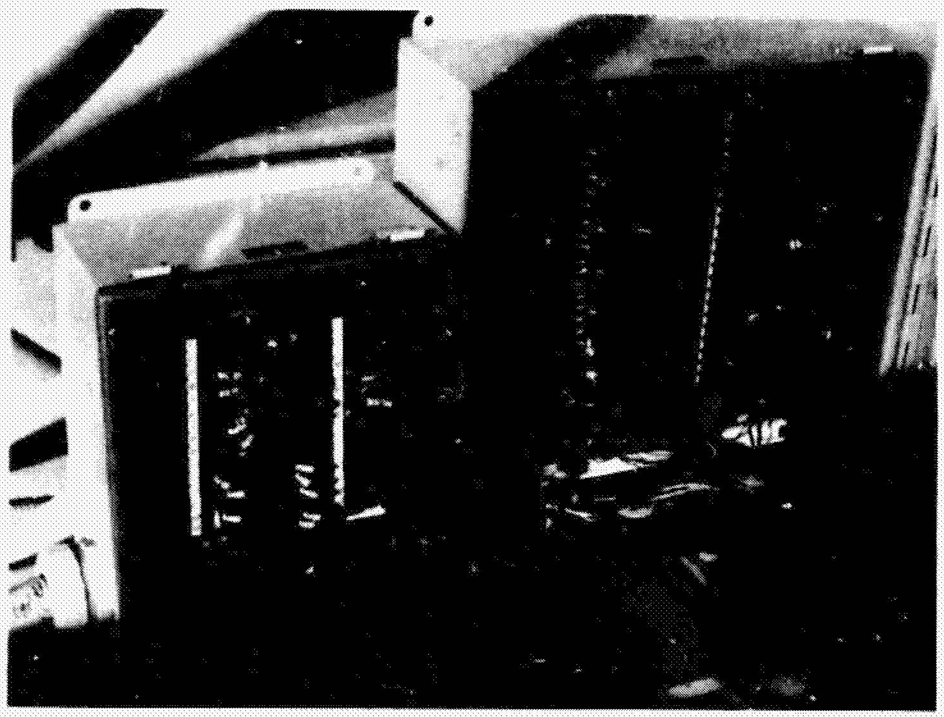

Note: The power and control-related lines to the Data Van for instrumentation power, lights, air conditioning, voltage and frequency control, normal and emergency stop, and general service power are connected in the left terminal box EC. The next or central terminal box EA contains the connections for signal wires to the computer for monitoring power plant shutdown functions such as underspeed, overspeed, vibration, low oil pressure, high oil temperature, and shaft seal flush water.

Figure 2-26. Left Terminal Box EC and Central Terminal Box EA

Note: Located in the right-hand terminal box EB are the connections for instrument wires relating to power plant information such as bearing temperatures and loads, throttle position, and alternator bearing and winding temperatures. Also, all of the process instrumentation lines for fluid flow rates, pressures, and temperatures are connected in this terminal box on the way to the computer.

Figure 2-27. Right Terminal Box EB

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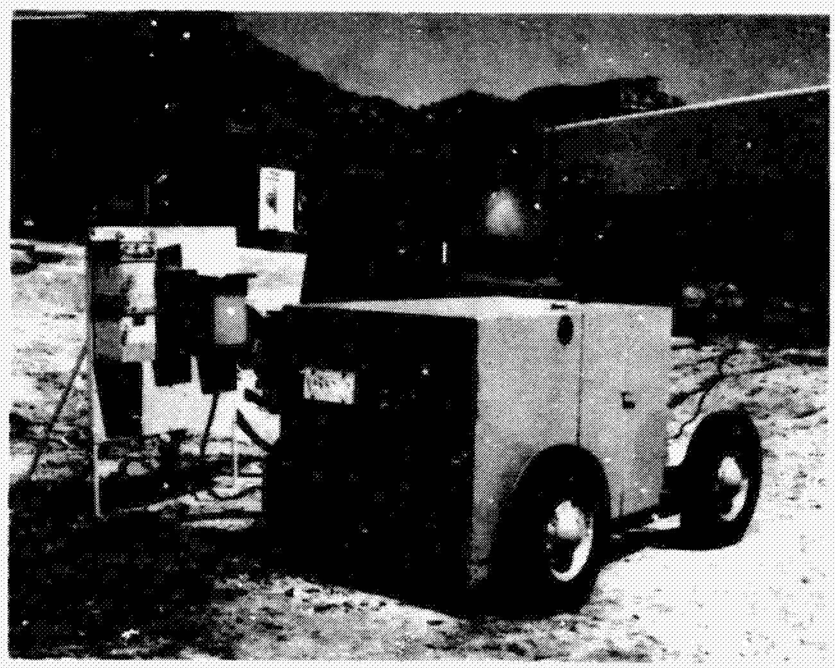

Note: The Utility Power Panel is shown in the left foreground. Closer to the right is the Auxiliary Generator. Beyond can be seen the Covered Load Bank, the Data Van to the right, and the Power Plant Building to the left.

Figure 2-28. The Utility Power Panel

SECTION III

DESIGN AND FABRICATION

A. DESIGN

1. HSE Power Plant

The HSE and the HSE power plant were designed by HPC. The design relied heavily on the development work done by HPC with the 50-kW prototype plant prior to this Project, and on recommendations and equipment available from suppliers. Prior to this Project, a conceptual design of a 1-MW HSE power plant was completed. In this design, the expander relied heavily on the technology and practices of the compressor industry. Within this Project, HPC advanced the design from conceptual to final. In this process, the method of construction of the HSE housing was changed from casting to fabricating. Numerous benefits resulted, including strength, materials selection, flexibility of manufacture, and flexibility of design, which resulted in a true geothermal machine rather than an adapted compressor. The relationship of the new machine to the existing compressor industry is maintained by the use of rotors which were cut by a licensee of SRM to the same profile specifications as those used in compressors, as reported earlier.

During the design and fabrication of the HSE and power plant, numerous recommendations were offered by JPL. Many of these were incorporated -- sometimes much later. In providing technical management of the HPC contract, JPL policy was not to be insistent regarding design recommendations, except in matters of safety and quality. It was the stated purpose of this Project to evaluate a proprietary machine and not to control its design or development. The JPL requirements regarding safety and quality did result in a more formal design effort than HPC had originally planned. As stated earlier, the design details of the HSE were released at the discretion of HPC. Description of the expander and the power plant are presented in Section II.B. and C. and in Appendix A.

2. Test Support Equipment

JPL designed the load bank, the Data Van and the data system on a schedule compatible with the needs of this Project.

a. Load Bank. The design of the transportable load bank was based on equipping two commercial electric duct heaters with blowers, switches and protective interlock circuitry, so that resistive load units could be added in increments of 50 kW or more, to a total of 1000 kW. The load bank is described in Section II.D.

b. Data Van. The Data Van design entailed modifying a used NASA trailer to house the instrument and control consoles and supporting gear. A removable stair and a vestibule were provided to facilitate entry through one of the standard rear freight doors. The doors were retained as security doors. A window was installed in a forward removable panel, the lighting was modified, and an air conditioner was installed for heating or cooling. An air supply with charcoal filter was specified to provide an environment suitable for the electronic instruments. Instrument racks were obtained from surplus stores and reassembled in suitable configurations in the Data Van. For additional descriptions of the Data Van see Section II.F.

c. Data System. The data system was designed by JPL to use a desk-top computer equipped with a programmable analog to digital multiplexer, or multiprogrammer, for scanning the instrument signals. This state-of-the-art technology was available at a cost that was little more than originally budgeted for strip chart recorders. The data system is described in Section II.E.

During the design phase, JPL performed design reviews and coordination as appropriate. JPL also prepared a checklist of all the electrical parameters in proper grouping, to ensure that all of the interface requirements among the power plant and the control and instrument support systems would be satisfied.

B. FABRICATION

1. HSE Power Plant

The HSE and the HSE power plant were fabricated by HPC in Mission Viejo, California. HPC began procurement negotiations with its suppliers in January 1976. JPL required HPC to follow formal competitive bidding procedures, and to submit HPC purchase orders of $10,000 or more to JPL for approval prior to their execution with HPC suppliers. These purchases were required to meet JPL terms and conditions, and thus took longer than was originally planned. Moreover, JPL required HPC to set up a JPL-approved quality control system, and performed critical source inspections with HPC.

HPC occupied its shop facility in Mission Viejo in March, and made preparations for receiving the first raw materials. The fabrication continued until August 18, 1977, when acceptance testing was first attempted, and then until December 4 1977, when the acceptance testing was completed. After acceptance testing and in-place delivery to JPL, the electrical service panel on the power plant was revised to provide 480-Volt, 100-amp service each for two 100-hp pump motors.

The most serious delay during the fabrication resulted from a slip in the delivery of the gear box. A natural gas supply shortage in the eastern United

States during the winter of 1976-1977 caused a lengthy shutdown of a foundry which supplied the gear box manufacturer. Then, after the supplier resumed production, a furnace was used prematurely, resulting in a bad billet which was delivered to the manufacturer only to be rejected. The impact on the completion schedule of the power plant, and on the cost of this Project, was significant.

A chronology and schedule of the details of the fabrication of the HSE power plant are interesting but are not essential to this report, and are not included here. Further, much of this information is proprietary. A few details can be found in the HPC Final Report (Ref. 5).

2. Test Support Equipment

The test support equipment was fabricated by JPL and its suppliers concurrently with the fabrication of the power plant.

a. Load Bank. The load bank was fabricated by Hollins Electric and Engineering Co., Los Angeles, California, according to JPL design specifications.

b. Data Van. The Data Van modification was done by the JPL Plant Maintenance and Service Section personnel under the supervision of JPL Facility and Construction Section engineers, who did the design.

c. Data System. The data system was assembled by members of the JPL Propulsion Systems Section.

SECTION IV

TEST SITE

The availability of a suitable test site is a major factor in the planning and execution of a hardware test project such as this. For a variety of reasons such as Project policy objectives and credibility, as well as the specific needs of the HSE, the idea of testing the expander on artificial brine was reviewed and rejected early. It was believed that many of the questions to be answered in evaluating any wellhead device could only be answered by testing at or near the wellhead.

At the time of the formulation of this Project in late 1973, the number of large or moderately large wells in low salinity, high enthalpy liquid-dominated fields in the United States was small. This situation might have severely restricted the size of the expander and the test matrix around which to plan this Project because the decision had been made that the first testing would be done on low salinity brine -- only subsequently would testing be done on very highly saline brine such as was available in the Salton Sea KGRA. However, nearby, at Cerro Prieto, Mexico, suitable sites for testing with low salinity brine were potentially available. Two other factors were important. First, HPC had established good rapport with CFE personnel during the prototype development and testing which Roger Sprankle had done in Mexico. As a result, HPC had a standing invitation to return for additional testing. Second, NSF, for whose goals this Project was formulated, looked with favor on the prospects of foreign country involvement. This meant that Project planning was permitted a wider scope than would have been possible otherwise. In particular, this planning made a 1-MW wellhead power plant feasible. A test spectrum planned for a 1-MW expander of 70% machine efficiency requires approximately 550,000 lb/h of saturated brine for 100-psia inlet, noncondensing operation under full load. This illustrates something about the problem of matching test equipment and prospective test sites -- many wells do not produce at this high rate. It was not assumed that the first test site would be at Cerro Prieto, but it was important to know that a suitable site did exist and was potentially available.

A. SITE SELECTION REVIEW PROCESS

The site selection process became formalized in June 1976 with the distribution of a site packet to prospective site operators. The site packet consisted of a cover letter, a symposium paper on the expander, a questionnaire, a test plan outline, an abbreviated schedule and the distribution list. The list was classified into four categories: Group A, organizations known to have prospective sites; Group B, organizations known to have geothermal resource interests; Group C, organizations affiliated with Group A; and Group D, organizations known to have special interest. The site packet is included in Appendix C.

1. Questionnaire

The questionnaire dealt with 20 test site parameters listed in Table 4-1. These are described more completely in the questionnaire itself (see Appendix C).

2. Selection Process

The site selection process followed the sequence listed below:

(1) Prepare the site packet.

(2) Obtain ERDA/DGE concurrence to use the questionnaire and distribution list.

(3) Distribute the packet.

(4) Review and classify the responses.

(5) Make follow-up contacts with the respondents as appropriate.

(6) Visit candidate sites to gather or review technical data, and probe the nontechnical issues.

(7) Prioritize the sites on a technical basis for three site types.

(8) Review the information on the nontechnical issues to see if they affect the selections made on a technical basis.

(9) Make the primary selections.

(10) Review the findings with ERDA/DGE.

(11) Receive ERDA/DGE selection concurrence.

(12) Document the arrangement contractually as appropriate.

Table 4-1. Test Site Parameters

1. Salinity:

Low	0-3% TDS
High	20% TDS

2. State
3. Flow Rate
4. Production Reliability
5. Waste Disposal
6. Coolant Supply
7. Condition of Well
8. Topography and Accessability
9. Well Performance Data
10. Experience of Site Personnel
11. Site Test Equipment
12. Shop Facilities
13. Corrosion and Materials Data
14. Non-Condensables Content
15. Entrained Solids Content
16. Dissolved Solids
17. Chemistry Laboratory
18. Turn-Down and Shutdown Requirements
19. Test Participation and Basis
20. Site Use Liability Requirements
21. Site Permits
22. Site Preparation and Restoration
23. Open Site
24. Nearest Commercial Airport and Travel Time
25. Nearest Hospital and First Aid
26. Publicity

Forty-eight site packets were sent (see Appendix C). The group A list, organizations known to have prospective sites, numbered eight. The responses were approximately as anticipated. After screening out those sites clearly not suitable for technical reasons, site inspections were made of the others by the JPL principal investigator and the HPC chief engineer. It quickly became obvious that both for technical and nontechnical reasons, a Phillips' well in the Roosevelt KGRA in Utah would be preferred for the first test site. Selection of a second site for testing on high salinity fluid was deferred pending test results at the first site.

B. SELECTED SITE

1. Technical Details

Two Phillips' wells at the Roosevelt KGRA were plausible candidates. These were Well 13-10 and Well 54-3. Each had adequate flow and high enthalpy and each was situated beside a pit which had been used in drilling and flow testing the well. The proposed test plans contemplated using the pit as a heat rejection pond for a condensing operation. However, due to the topography and placement of the pits, Well 13-10 was the better choice. The pit at Well 54-3 was upslope from the well, and placement of the HSE to allow discharging into the pit required placing the HSE hundreds of feet from the well, a clearly undesirable prospect. At Well 13-10 the layout permitted placing the HSE near the well with easy drainage to the pit. Further investigation with Phillips revealed other important contrary considerations. Some of the flow rates required for testing the HSE were not suf icient to prevent Well 13-10 from slugging, and bypassing fluid to the pit would have been necessary. This would have hastened the filling of the pit. Moreover, Phillips had scheduled installation of the FTF at Well 54-3 to allow the well to flow for 6 months to evaluate the reservoir. The Project use of Well 13-10 during the reservoir evaluation was not an available option because it would have interfered with the reservoir test. Thus, as if by default, Well 54-3 became the selected test well. This brought nontechnical advantages as well as a mixture of technical advantages and disadvantages. The most notable nontechnical advantage was the obtaining of permits, which Phillips handled effectively in profuse detail for its own needs. The test activities of the HSE at the site were written into the Phillips permit applications along with its own. In addition, Phillips had developed sources of supply for roustabout and supervisory assistance at the site for its own needs and these became available for hire by the Project. The most important technical advantages of the site were the performance characteristics of Well 54-3, the incorporation of a high-pressure separator into the Phillips FTF, and the disposing of the waste water by Phillips. The Phillips FTF is shown schematically in Figure 4-1. The high-pressure separator made steam and water available for recombining in measured amounts as feed to the HSE. This fact resolved the question of whether flow and enthalpy would be determined from measurements upstream or downstream from the HSE. The need to place the HSE more than 300 feet from the well for topographical reasons significantly added to the installation costs. Consequently, an extensive study and review of the costs and benefits of a simplified test process based on hot water only, versus a test process based on using the steam and the water, was made for ERDA. The test options are discussed

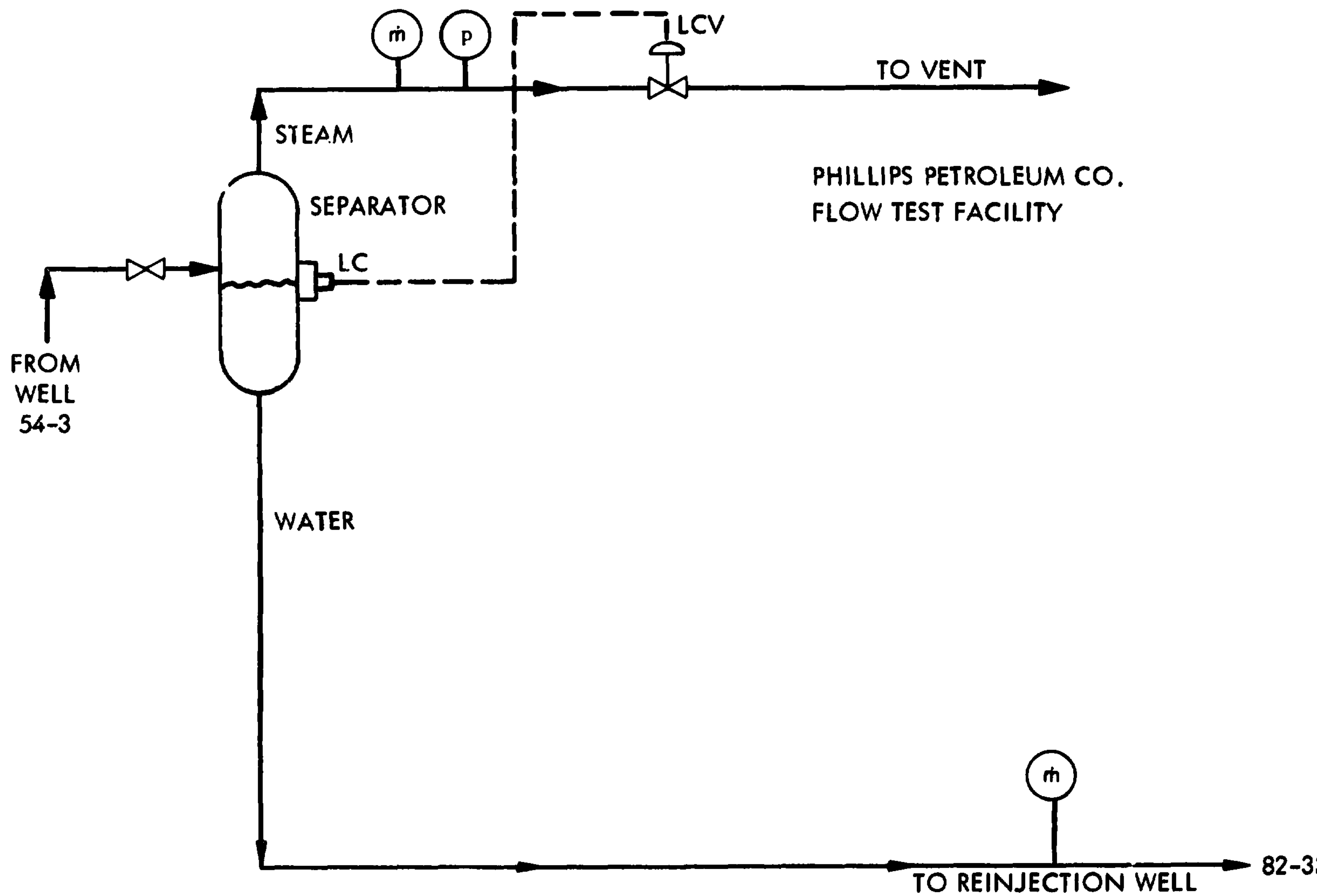

Figure 4-1. Phillips FTF

later. Authorization was received to install the more versatile test process for noncondensing testing by including the expenditure of funds which were to have been provided for condensing equipment.

2. Conditions of Occupancy

Several conditions of occupancy were imposed by Phillips. These included a comprehensive review by Phillips of the JPL process installation, and a requirement that JPL contract through Phillips for supervisory assistance in the fabrication and installation of the process equipment from the same consultant whom Phillips had arranged to have on site for its own needs (Lee Peiffer of Peiffier Associates, Inc.). These conditions were welcomed by JPL and were broadened to include the process piping design and piping hardware procurement by Phillips at cost, based on the JPL process design and specifications. The piping design was subsequently re-engineered in the field, primarily by the supervising consultant and the JPL principal investigator, with the concurrence of Phillips. This made the installation more compatible with the Phillips FTF.

The FTF was on land leased by Phillips from the United States Government. A condition of the Phillips' lease was that the leaseholder report to the United States Geologic Survey details of the usage of geothermal fluids produced (i.e., quantity, condition and purposes). Therefore, it was a condition of the Land Use Agreement (Appendix D) that JPL report to Phillips details of fluids usage for testing the HSE. Information on the quantity of steam and water at saturation received from the FTF, the temperature and quantity of water returned, and the electrical energy generated was sufficient for this purpose (see Waste Water Management section below). Other conditions of occupancy included a Phillips sole operator role for FTF equipment, and no guarantee of "the range of conditions, duration, quality or quantity of fluids provided."

3. Notable Selection and Usage Factors

All of the parameters included in the site selection questionnaire were important, but three site-dependent factors received special consideration. These were waste water management, pressure stability of the test fluid supply, and scale formation.

a. Waste Water Management. A very significant technical condition of occupancy was that waste water from the HSE test operation be returned to the disposal line of the FTF from which it was taken. This meant that it had to be repressurized to separator pressure or above for injection into the line. The disposal pumping needs of the Project were studied in conjunction with the disposal requirements of the Phillips' FTF. The disposal line ran cross-country and through a wash to disposal Well 82-33, located 1.4-miles pipeline distance away and 300-feet lower in elevation. The flow versus pressure characteristics of disposal were not known with high confidence, and Phillips considered it advantageous to provide a pressure boost for disposal, if the boost could be provided reliably. Sharing of pumping costs was considered, along with the equipment availability and schedules, and reliability of the method.

Several approaches to the pumping needs were reviewed. These included a contracted pumping service, the use of rented engine driven pumps, the use of purchased engine-driven pumps, and the use of electrical pumps. Two options were considered for driving electric pumps. First, with electricity from an electric power utility transmission line, about 9/10 mile from the site, or second, with electricity from the HSE power plant. Utility power was attractive in concept because it would have meant an assured supply of electricity for the general site needs of both Phillips and this Project. A utility price quote of $130,000, up and down charge for a 500-kW transformer substation plus monthly service charge, all to be borne by this Project, ruled out this option. Loss of this option ruled out any possible consideration of connecting the HSE power plant to the electric grid for test or demonstration purposes. A companion cost for this option was for four electric pumps at $26,000 each, three to be purchased by Phillips and one by JPL.

Finally, it was agreed that Phillips would proceed with its disposal needs as if the HSE were not at the site, and JPL would return waste liquid to the disposal pipe by any suitable method. The method chosen by JPL was a combination of two electric pumps drawing power from the HSE power plant, and the use of a waste holding tank to make a bootstrap start possible, since, during start-up, waste would accumulate before electric power became available. This approach was possible because two suitable used pumps and motors were available for refurbishment for a price and delivery acceptable to this Project. The holding tank idea was broadened to provide sufficient storage for waste accumulation during testing at high waste flow rates for periods estimated to be long enough to complete a single test, provided at least one pump was in operation. Sufficient storage was provided by a pair of 20,000-gallon tanks. By switching back and forth between tests of high and low waste flow, the waste disposal requirement could be met for all test conditions.

The points of withdrawal and return of water from the FTF for HSE use were upstream from the FTF flowmeter. This meant that fluid usage by the Project interfered with the water flow measurements of the FTF. On the average, less liquid was returned than was received because flashing of some liquid took place during passage through the expander. However, on a short-term basis, more could be returned than was being received by drawing down the inventory in the holding tanks. Accordingly, it was a requirement that the amounts of water received and returned be reported to Phillips on a daily basis. During the 1979 testing this information was requested on an hourly basis. Steam usage was also reported to Phillips, but this information was not technically important because the steam was withdrawn downsteam from the point of measurement in the FTF on its way to an atmosphere vent. The daily fluids usage data for the testing in 1978 and 1979 [illegible] in Tables 4-2 and 4-3. The data for Table 4-2 were obtained mostly by [illegible] integration of fluids usage plots (Appendix E) which were prepared [illegible] the data from the 1978 operating log (see Figure 2-16). The

Table 4-3. Geothermal Fluids Utilization: 1979

Test Run Date, 1979	Test Duration, h	Electrical Output, kWh	Steam from Separator,[a] 10^3 lb	Water from Separator,[a] 10^3 lb	Water to Disposal, 10^3 lb	Level Change in Banker Tanks, in.
9/3	15 sec	0	0	0.3	0	-50
9/4	--	0	0	1.38	0	10
9/5	0.05	30	1.12	9.88	0	5
9/6	0.45	--	1.47	14.3	0	15
9/7	2.6	210	10.0	43.6	0	20
9/8	3.0	150	14.25	86.7	129	-58
9/21	7.3	1140	30.3	318.0	298.5	13
9/25	5.9	1350	0	569.4	533.7	-29
9/28	6.0	1800	2.54	666.7	614.4	-58
10/12	5.7	1560	0	484	457	-34
10/16	3.4	1140	0	596	509	- 9
10/17	2.08	390	0	161	123	3
10/18	5.72	1080	0	475	342	5
10/20	4.68	630	0	368	282	5
10/23	5.92	2340	0	810	689	-15
10/25	5.15	2190	0	121	66	22
10/27	8.05	4710	92	901	852	-39
10/28	4.25	2220	70	237	215	- 5
10/29	0.8	210	16	1	0	2
11/3	4.35	1110	30	257	213	- 3
11/4	0.88	60	0	71	0	0
11/6	8.52	480	0	465	408	-18
11/11	3.71	1560	24	330	328	-18
11/13	--	3390	84	595	311	22
11/14	Well was shut in					-48
TOTALS:	88.5 (100)[b]	27750	375.7	7582.3	6370.6	

[a]Does not include bleed to keep pipes hot during stand-by.

[b]From elapsed time meter.

NOTE: Some water from the Banker Tanks was put in the pit on 9/4, 9/7, 9/15, 10/20 11/16 to permit equipment repair, and at the completion of the tests.

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[a]Does not include bleed to keep pipes hot during stand-by.

[b]From elapsed time meter.

NOTE: Some water from the Baker Tanks was put in the pit on 9/4, 9/7, 9/15, 10/20 11/16 to permit equipment repair, and at the completion of the tests.

data for Table 4-3 were obtained directly from the 1979 operating log (see Figure 2-19). Additional information about the data and the plots are included in Appendix E.

b. Pressure Stability of the Test Fluid Supply. Testing of the HSE can be performed only if it is provided with a stable fluid supply pressure. Therefore, at the invitation of Phillips, an inspection of the FTF early in its operation was made by JPL and HPC. This inspection took place on October 18, 1977, prior to the start of the installation of the HSE test facility. At this inspection, the FTF was perturbed to simulate placing the HSE into operation, or stepping through normal load changes, in order to test the response of the FTF. Pressure stability and level control in the separator were observed and seen to meet the HSE test requirements. Subsequently, necessary changes were made by Phillips in the method of controlling the FTF before the installation of the HSE test facility. A smaller control valve of a type less susceptable to scale deposits was installed in parallel with a manually adjustable bypass (Figure 4-2). These changes resulted in the liquid level and pressure in the separator being stable in normal operation but easily upset by the HSE test operation in 1978. The consequences led Phillips to authorize a JPL revision of the FTF pressure and level control method during the HSE test period which was then carried over, in principle, into the 1979 FTF design (see Figure 4-3).

c. Scale Formation. Paramount in the performance testing of the HSE is the formation of scale on the rotors during testing. Since the HSE geothermal application was conceived as a wellhead device, scale formation within the machine was expected. Accordingly, HPC designed and fabricated the machine to be compatible with the scale deposits. One feature of this design was clearances within the machine which would be filled in with scale deposits on the rotors and rotor case interior during operation. Until these clearances close, the machine is unfinished and suffers degraded performance because of leakage past the rotors.

During an inspection of the Well 54-3 site on December 1, 1976, JPL checked a sample of scale from a surface pipe using battery acid. The scale bubbled vigorously. This observation, the well water analysis (see Appendix F), the process specifications for the FTF operation, and the large pressure drop the fluid would experience in passing through the HSE, led the JPL investigator to conclude that scale deposits would occur within the machine during the testing. This conclusion was reached against the background of the Phillips' view that scaling would not occur in the surface pipe. Actually, scaling in the machine did not occur during the 1978 testing but it did occur in the production well and in the FTF surface pipe in amounts sufficient to interfere with the testing of the HSE. The cause was believed due largely to the need to operate the FTF outside of the specified conditions because of the initial limitations imposed by the disposal well. This matter was reviewed carefully in preparation for the 1979 HSE tests. Two reasonable options appeared available -- either to bypass the FTF part of the time and flow directly to the HSE, or to operate the FTF

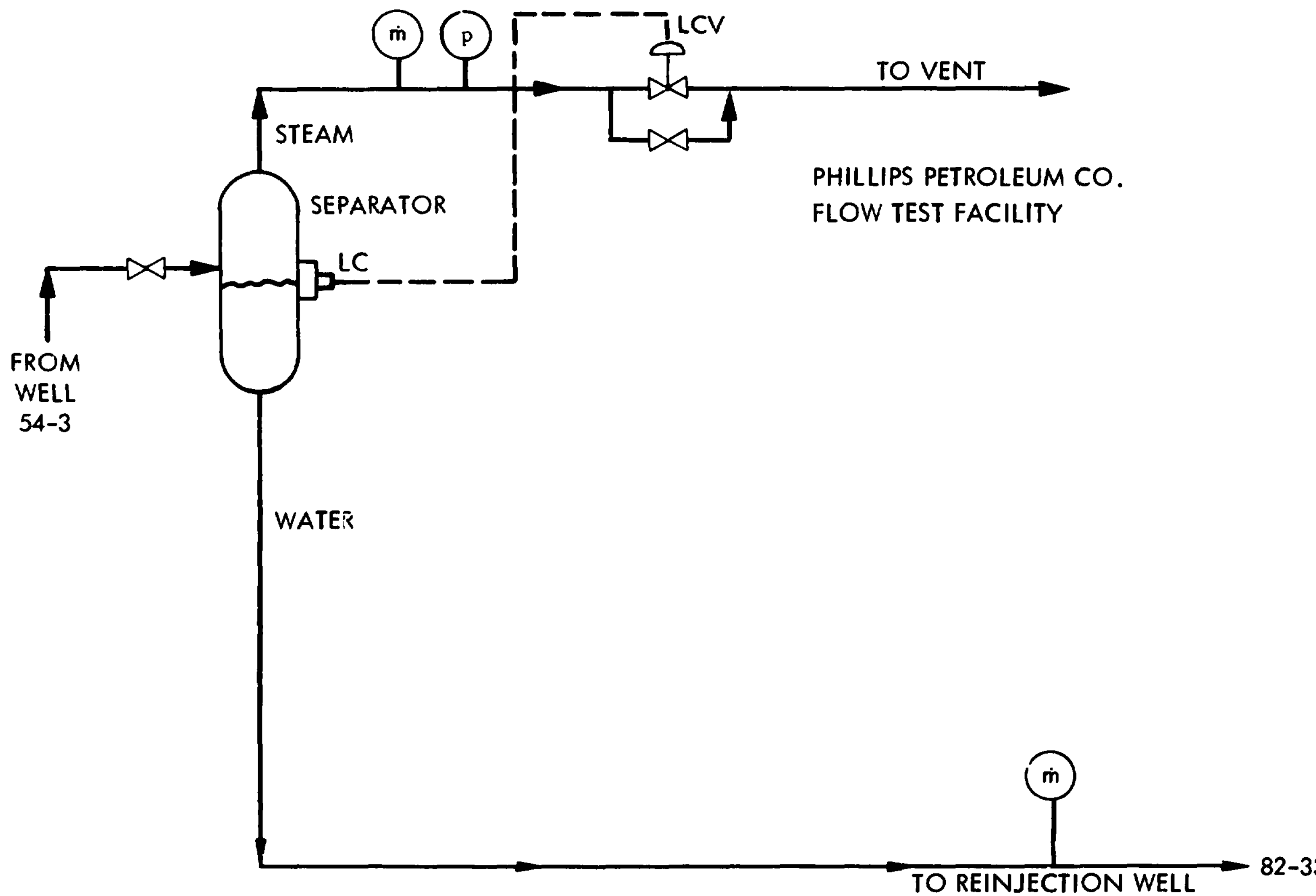

Figure 4-2. Phillips FTF, Revised Prior to HSE Installation

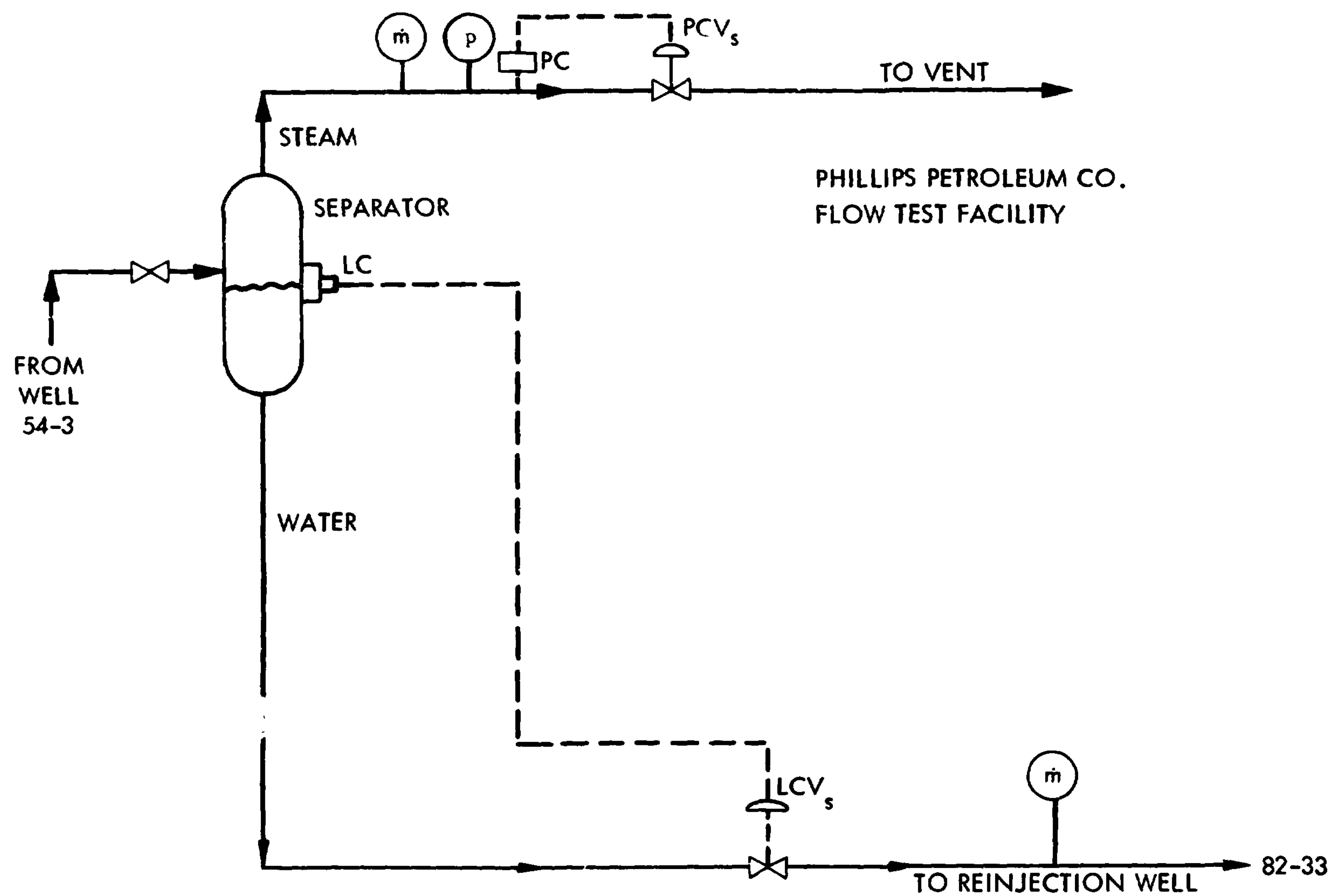

Figure 4-3. Phillips FTF after May 19, 1978

separator at wellhead pressure so that fluids could be delivered to the HSE essentially at wellhead pressure. The premise in bypassing the FTF was that since scale deposits occurred there, they would occur in a parallel process if conditions were comparable.

Bypassing the FTF would have required adding a valve at or near the wellhead and running another pipeline to the HSE. The disadvantages of this approach were the added cost, the inability to measure directly the fluid received, and the prospects of slug flow forming in the pipe. The advantages of operating the separator at wellhead pressure avoided these disadvantages and created no others. This matter, along with schedules, etc., was discussed with Phillips in Salt Lake City on January 15, 1979. The Phillips' operating plan for the FTF was to restrict the flow at Well 82-33 and to allow the separator to "ride the well" with the separator pressure maintained at 385 psig. Lower separator pressures would not be available, and the HSE testing was to be planned accordingly. In actuality, a substantial pressure drop was taken in the FTF between the well and the separator during the 1979 HSE testing, and Phillips injected an assortment of scale inhibitors into the main pipe near the wellhead much of the time to study and control the scale formation of the FTF. Whether the departure from the operating plan of the FTF resulted from a well "blowout" on June 8, or from a change in Phillips' test objectives was not ascertained, but scale deposition in the HSE did not occur. Attempts to work around this problem are discussed in Sections I.B. and II.D.

SECTION V

PERFORMANCE EVALUATION METHODOLOGY

A. THEORY

For the purpose of performance evaluation of the HSE, the expander efficiency η is defined as:

$$\eta = \frac{P}{\dot{m}\,(h_1 - h_{2s})} \qquad (2)$$

where P = shaft output power
$\dot{m}$ = flow of fluid through the HSE
h_1 = specific enthalpy of fluid entering the HSE at inlet pressure p_1 and inlet temperature t_1

and h_{2s} = specific enthalpy which would result from the isentropic expansion of the fluid from the HSE inlet condition to the outlet pressure p_2. The value of h_{2s} is calculated from h_1 and the thermodynamic properties of the fluid at the inlet and outlet pressures.

P, $\dot{m}$, and h_1 must be determined experimentally.

This is the standard equation for turbine efficiency under steady-state operation which is equal to the ratio of the actual work done by the expanding fluid to the work of an ideal expansion over the same pressure interval.

Prior to the 1979 testing, the question was raised as to whether throttling losses in the throttle, or flow control valve, of the expander were significant. As a means of resolving the question, a pressure tap was installed in the throat of the throttle for the 1979 tests by drilling a passage through the throttle gate and control rod to a pressure transducer designated as p_D. This permitted calculating expander efficiency on the basis of pressure p_D actually entering the rotor pocket A (see Figure 2-1) rather than on the basis of the upstream pressure p_1 normally used. If throttling losses are significant, the calculation based on p_D should bias the calculated efficiency in favor of the expander since kinetic energy gained by the fluid during throttling imparts momentum to the rotors, resulting in an unmeasured bonus for this calculation. Measurement of pressure p_D, and the calculation of efficiency based thereon, were included in some of the 1979 tests. This efficiency is designated as effPd% by the computer.

Immediately after the 1979 testing, examination of the test data and the calculated results revealed that under some test conditions of high expander load the measured exhaust pressure p_2 varied erratically, perhaps from buffeting by exhaust fluids issuing underexpanded from the exhaust ports. Therefore, the expander machine efficiency was calculated also on the basis of the state of the exhaust fluids determined by temperature t_2 rather than pressure p_2 since the temperature measurement was not similarily affected. Efficiency so calculated is designated as eff2% or effT2% by the computer to contrast it with eff%, the expander efficiency based on pressure. The pressure-based eff% is preferred for all 1978 tests and for all 1979 tests having steady exhaust pressure measurements.

B. TEST PROCESS FUNDAMENTALS

The means of determining P, $\dot{m}$ and h_1 in the efficiency equation depends on the test process selected. The measurement of the shaft power, P, by torque and rpm transducers was considered. In fact, the HSE shaft coupling to the speed reducer was provided with a removable section to permit insertion of these transducers. However, since the HSE drives an alternator whose electrical power output, P_e, can be measured accurately, this method was selected on the basis of cost and reliability. This led to the requirement that the alternator losses, a, and the gear box losses, b, be determined as a function of operating conditions of power factor and load. Thus,

$$P = P_e + a + b \qquad (3)$$

(This usage of a and b is not related to the a(J) and b(J) calibration coefficients discussed earlier in Section II.E.3.)

The alternator and gear box losses were determined from data obtained from the original equipment manufacturer. The alternator losses were actually measured in a comprehensive calibration prior to delivery; the gear box losses were calculated for each of the three gear sets from a computer program based on theories of bearing and gear mesh losses. The loss data and derivations of expressions for a and b are contained in Reference 3 and are summarized in Appendix G.

The above expression for shaft power P is not exact. It ignores the 7-1/2 hp (5.6 kW) load of the oil pump which was installed on the gear box. This pump load is independent of power plant load and varies with the temperature of the oil and the pump rpm. These parameters were maintained constant during the testing. The pump supplies oil for the HSE and the gear box. If the pump supplied only the gear box, it would be correct to add this load to the gear box losses, giving the HSE credit for this added power output. If the pump supplied oil only to the HSE, it would be proper to ignore this power output, treating it as a parasitic load as if the gear pump were actually installed on or within the HSE. The fact that the pump serves both equipment items means that the calculated HSE performance is penalized by the pump contribution to the gear box. On the other hand, the HSE imposes parasitic electrical loads on the power plant in order to operate. These loads include battery charger, grease injection motor, oil booster pump and oil purifier starting in 1979, a share of the oil cooling fan, etc. The parasitic loads were typically about 3 to 4 kW total, including the gear box share of the oil cooling fan and the air compressor for the automatic pipeline values. The calculated HSE performance receives a credit for its share of the parasitic electrical loads because they were not subtracted from the shaft output power. The penalty and credit offset one another; the difference is small, and has been ignored in the calculation of the HSE efficiency. The error is negligible, especially at large plant load.

The inlet enthalpy h_1 must be determined by indirect measurement, and in the typical case of two-phase flow, so also must the flowrate $\dot{m}$. It was recognized early in this Project that these two quantities could be determined by measurements made either upstream or downstream from the expander. For measurements upstream, the two-phase flow can be separated into vapor and liquid streams whose flowrates and enthalpies can be determined. The two streams can be recombined to give a stream of known flowrate and enthalpy to the expander. Thus,

$$\dot{m} = \dot{m}_v + \dot{m}_f \qquad (4)$$

and

$$\dot{m}h_1 = \dot{m}_v h_v + \dot{m}_f h_f \qquad (5)$$

or

$$h_1 = \frac{\dot{m}_v h_v + \dot{m}_f h_f}{\dot{m}_v + \dot{m}_f} \qquad (6)$$

where v refers to the vapor stream and f refers to the liquid stream. Since the two streams are at saturation, the enthalpy of each can be determined from tables or equations of the thermodynamic properties of steam and water by measuring the temperature or pressure. Thermodynamic corrections for salts in the liquid or noncondensable gases in the vapor can be made if their concentrations are significant.

The calculation of the efficiency by downstream measurement is similar to the above. For an actual expander, the sum of the power output and the thermal losses equals the product of the fluid flowrate and the actual change in the specific enthalpy of the fluid passing through the machine, or

$$P + \text{losses} = \dot{m}(h_1 - h_2) \qquad (7)$$

Thus,

$$h_1 = h_2 + \frac{P + \text{losses}}{\dot{m}} \tag{8}$$

In this work, thermal losses were negligibly small, so

$$h_1 = h_2 + \frac{P}{\dot{m}} \tag{9}$$

As with upstream measurement, the exhaust stream can be separated into two single-phase streams for determining h_2 and m, or cooling water at measured flowrate and temperature can be mixed with the exhaust to condense the steam in preparation for measuring the resulting flowrate and temperature. This latter treatment is compatible with the use of a contact condenser for vacuum operation. It is included in the calculations discussed in the following text.

The above analysis served as the basis for all process design studies made in this Project. To support the process design studies, calculations were made of mass flowrates and cooling water flowrates as a function of inlet pressure, inlet steam quality, exhaust pressure, and cooling water temperature for assumed machine efficiencies of 60 and 70% and a load of 1000 kW. The calculated results are independent of expander type for the selected parameters and are of general use in process planning (Appendix H). The selected ranges of interest were inlet pressures to 650 psia, inlet steam quality from 0 to 25%, exhaust pressure at 1 atmosphere or 3 psia, and cooling water temperatures of 80 and 100 F. From these calculations, in conjunction with process studies, a proposed test matrix for noncondensing operation was prepared of test points believed at the time to be attainable and adequate to permit a reasonable evaluation of the performance characteristics of the HSE (see Appendix I). (This matrix for noncondensing operation was submitted by JPL as a formal test plan and was approved by ERDA. It was later modified in the field to conform with available test conditions.) The process design studies served as a basis for defining test site requirements, and greatly simplified the site selection process. Once the test site was selected, the studies permitted evaluating the process options versus the cost.

C. PROCESS OPTIONS

Several of the process options which were formulated and studied are discussed below. These are grouped according to whether the flow and enthalpy are determined downstream as in Process Nos. 1, 2 and 3 or upstream as in Process Nos. 4, 5 and 6.

1. Process Number 1

Process No. 1 (Figure 5-1) is simple, not versatile and potentially inexpensive. Inlet fluid to the HSE is at constant enthalpy as determined by the

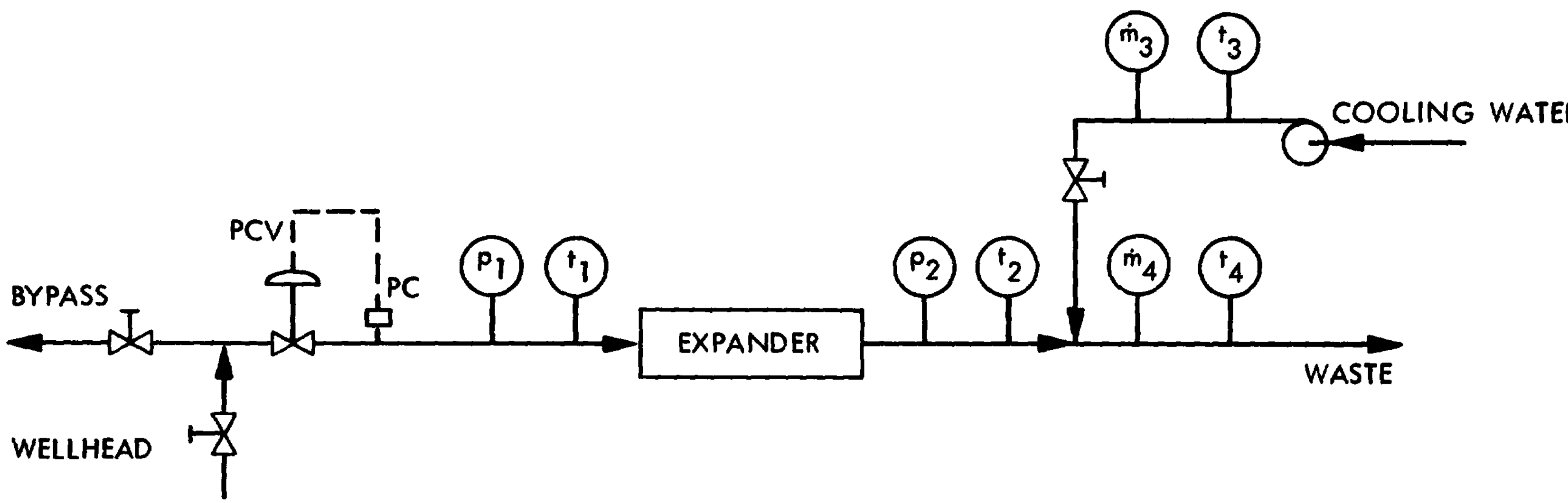

Figure 5-1. Process No. 1

well, and at variable pressure as determined by the pressure control valve. The pressure control valve could be replaced with a set of orificies in parallel for highly scaling brine. Cooling water, at measured temperatures, is mixed with the exhaust in an amount sufficient to condense the steam. Cost is minimized if the cooling water supply, heat rejection and waste disposal can all be provided by a pond or lagoon. The temperature and flowrate of the combined flow downstream from the HSE is measured after a suitable mixing length of pipe. The flowrate and enthalpy of the expander exhaust can then be calculated by a material and energy balance in and out of the point of mixing. The process requires that there be very little noncondensables for accuracy of flow measurement and enthalpy determination, otherwise the residual vapor phase must be removed from the combined flow stream and processed or measured separately. This minimum budget process was considered as especially suitable for the Salton Sea KGRA where a minimum of equipment would be an advantage. The process calculations shown in Appendix H are based on this process.

2. Process Number 2

Process No. 2 (Figure 5-2) separates the expander exhaust into vapor and liquid streams for measurement. It requires a separator but no cooling water or pump. Noncondensables are no problem; if they are known, suitable corrections can be made in the calculation. The process shares with Process No. 1 the advantage of a wellhead installation but similarly lacks versatility. This process was used for the 1980 testing in Mexico. Test versatility can be added to both Process Nos. 1 and 2 by installing a fractionator between the well and expander as shown in Process No. 3 (see Figure 5-3).

3. Process Number 3

Process No. 3 (Figure 5-3) uses a modified wellhead installation by inserting a fractionator between the well and the expander. The purpose of the fractionator is to allow bypassing either predominantly vapor or predominantly liquid from the fractionator to waste in order to decrease or increase the steam fraction of feed to the expander. The fractionator is essentially an inefficient separator but is less expensive although not as versatile. The versatility of the fractionator can be increased by throttling upstream of the fractionator. The supply pressure to the expander can be adjusted to pressures at or below wellhead pressure by the combination of valve settings into and out of the fractionator. A contact condenser installed downstream from the expander allows operation of the expander with a range of exhaust pressures at atmospheric pressure and below. Operating at exhaust pressures at and above atmospheric pressure requires only the installation of a valve or other flow restrictor in the expander exhaust pipe. A material and energy balance in and out of the condenser by measurements on single-phase fluid streams, as indicated in the figure, suffices to determine the expander flowrate and exhaust enthalpy.

This process was considered to be the best choice for all suitable sites. The installation is compact and very versatile. Associated processes such as

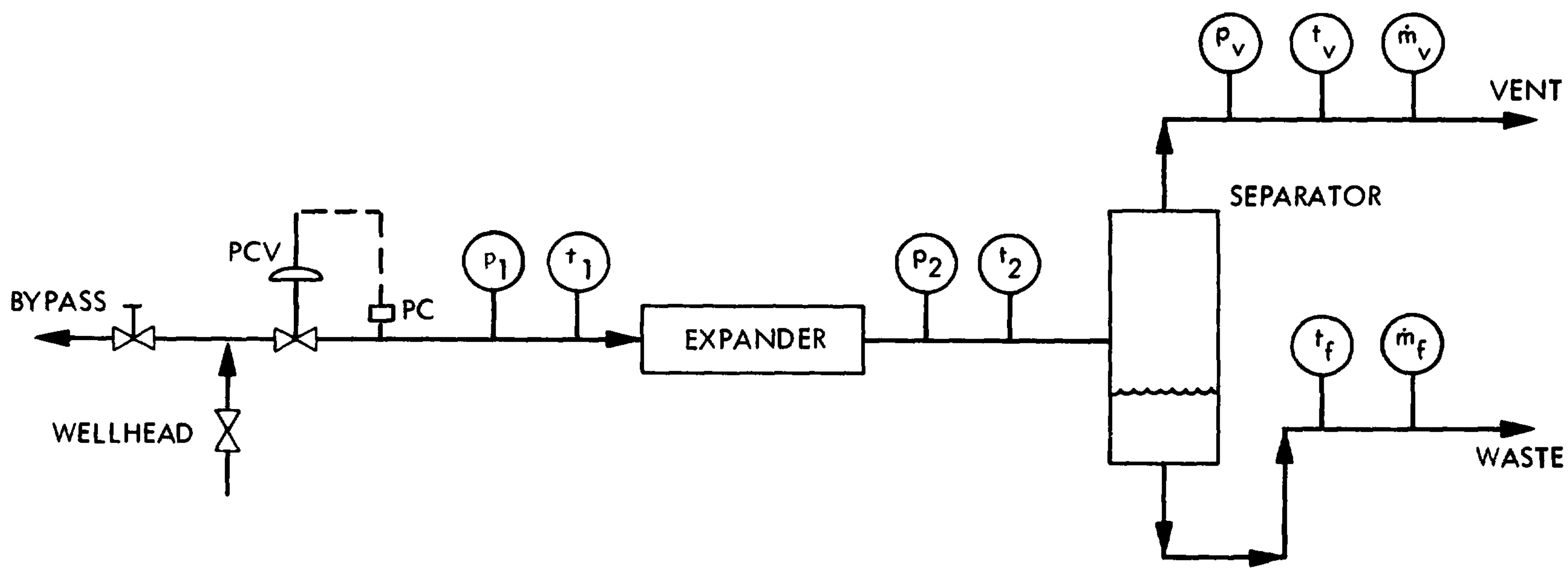

Figure 5-2. 'rocess No. 2

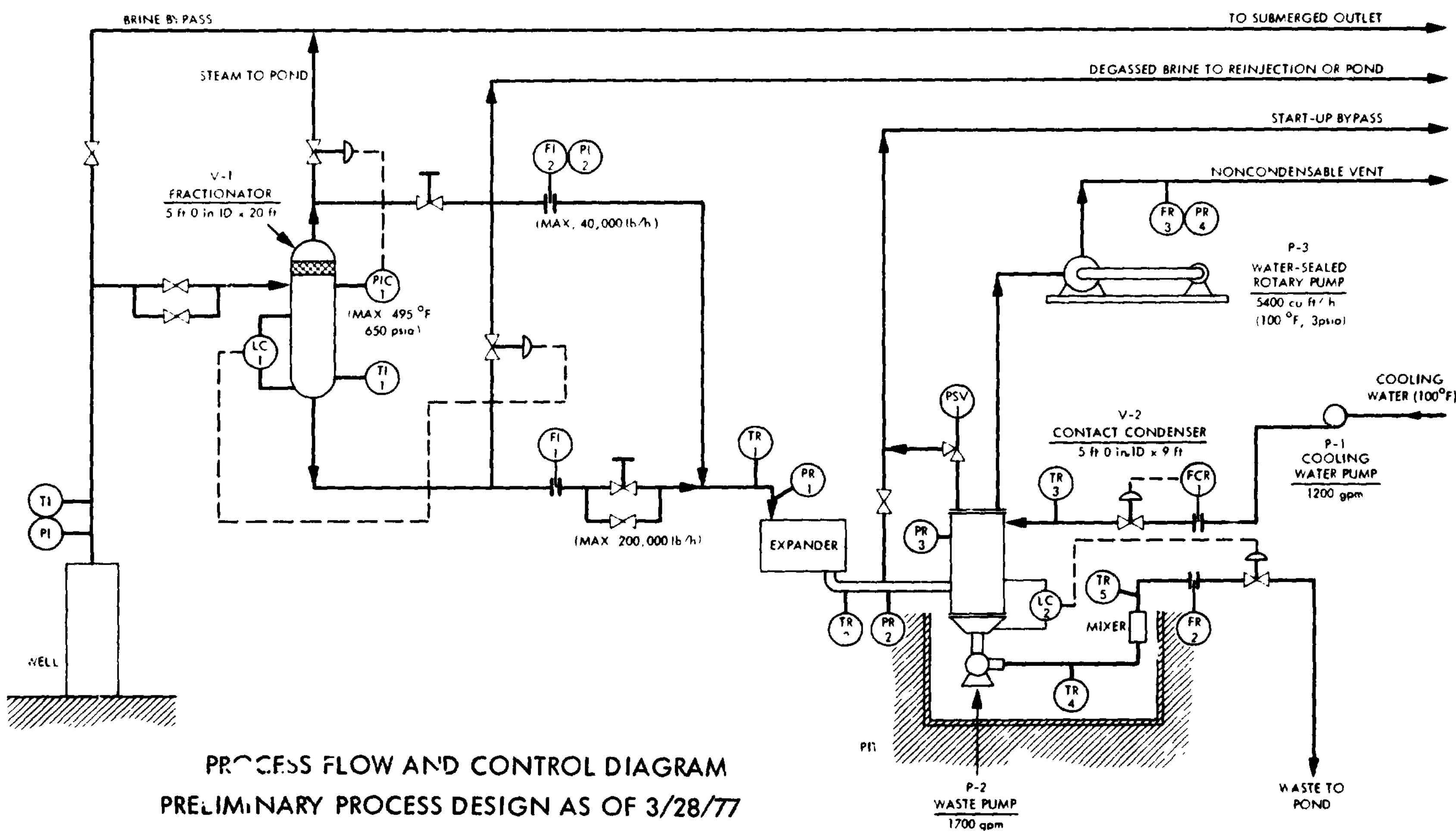

Figure 5-3. Process No. 3

spray cooling or waste disposal augmentation were recognized as possible site-specific necessities. The design study of this process was based on the design specifications of the HSE and not on the characteristics of any particular well. Some of the design parameters are shown in Table 5-1. The process was the basis of the planning for the proposed installation at Phillips' Well 13-10 in the Roosevelt KGRA at the time the use of that site was believed to be possible.

The use of Well 13-10 was ruled out for two main reasons. The Project use of this well would have interfered with the reservoir evaluation which was scheduled by Phillips, and the contemplated tests were not compatible with existing Bureau of Land Management authorizations obtained by Phillips. Therefore, Phillips' invitation for this Project to make use of the FTF at nearby Well 54-3 was very welcome. The need to place the HSE approximately 400 feet from the well and to repressurize the waste water for disposal, however, imposed unexpected costs on the Project. These costs were reflected in the process designs studied for testing at Well 54-3. The process designs were based on the Phillips' specification of a 385-psia operating pressure for the FTF separator.

4. Process Number 4

Process No. 4 (Figure 5-4) is the simplest, least expensive and potentially the most accurate method which was available for testing the HSE at Well 54-3. It entails receiving only liquid from the FTF and sending it throttled or unthrottled to the expander for expansion to atmospheric pressure. The liquid leaving the separator is saturated and, since its temperature can be measured easily, its enthalpy can be determined from the steam tables. A correction can be made for the dissolved solids. Ideally, the enthalpy can be determined from the separator pressure, but the pressure of gaseous impurities, if present, makes the pressure abnormally high. This can be checked by comparing the pressure and temperature measurements. If heat losses from the pipe downstream from the point of measurement are small, the flow to the expander nearby is essentially at constant enthalpy and so the inlet enthalpy h_1 is known. The flowrate can be measured in the all-liquid state leaving the separator using an orifice meter if the meter run is positioned to provide sufficient head to prevent flashing in the meter. The pressure to the expander can be held constant at or below separator pressure, less line losses, by means of the pressure-regulating valve shown in the supply line near the expander. With the provision for throttling the liquid from the separator, operating at the specified pressure of 385 psig, the inlet conditions to the expander are shown in Figure 5-5 as the solid curve of constant enthalpy which relates inlet pressure and steam quality. If the separator can be operated at successively lower pressures, the curve shifts, reaching the position of the dashed curve in the figure for a separator pressure of 200 psia. Thus, any operating point on or between the curves can be made available.

Table 5-1. Process No. 3 Design Parameters
Helical Screw Expander Support Equipment

I. Inlet Streams

	Brine	Cooling Water
Temperature, °F	280-500	100
Pressure at source, psia	50-650	atmospheric
Flow rate, lb/h		
Maximum	200,000	600,000
Maximum	10,000	30,000
Steam Quality at Expander Inlet, wt %	0-20	---

II. Fractionator - Separator

Maximum Excess Steam, lb/h	40,000 (50 psia, 280 °F)
Maximum Excess Brine, lb/h	100,000
Maximum Process Pressure, psia	650
Maximum Process Temperature, °F	500

III. Contact Condenser

Process Pressure, psia	14.7 normal 3.0 minimum
Process Temperature, °F	212 normal 140 minimum
Non-Condensibles, lb/h (200 ppm CO_2 in brine 20 ppm air in cooling water)	55 maximum

IV. Orifice Meter Runs

β, orifice diameter/pipe diameter	0.70 maximum 0.15 minimum

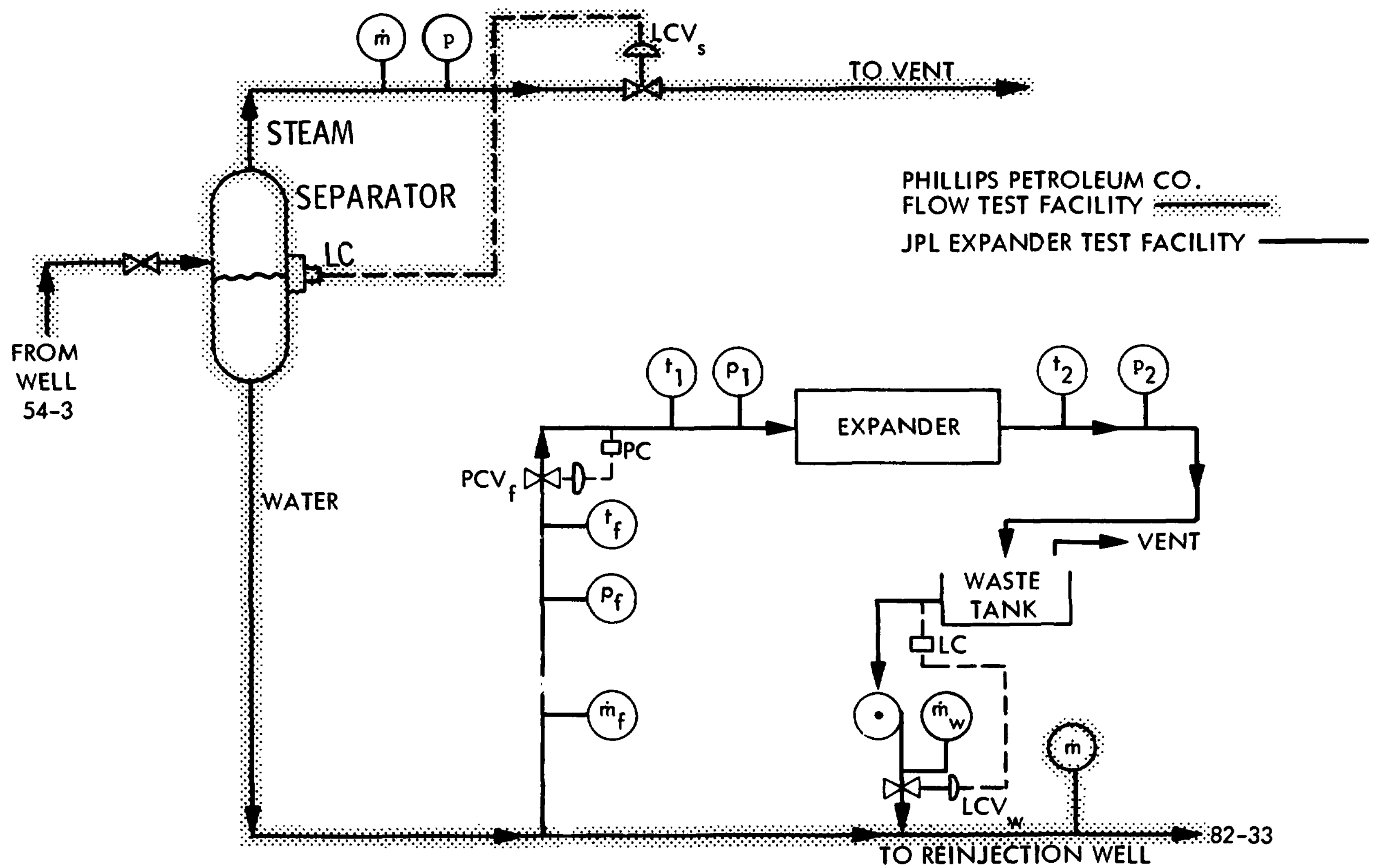

Figure 5-4. Process No. 4

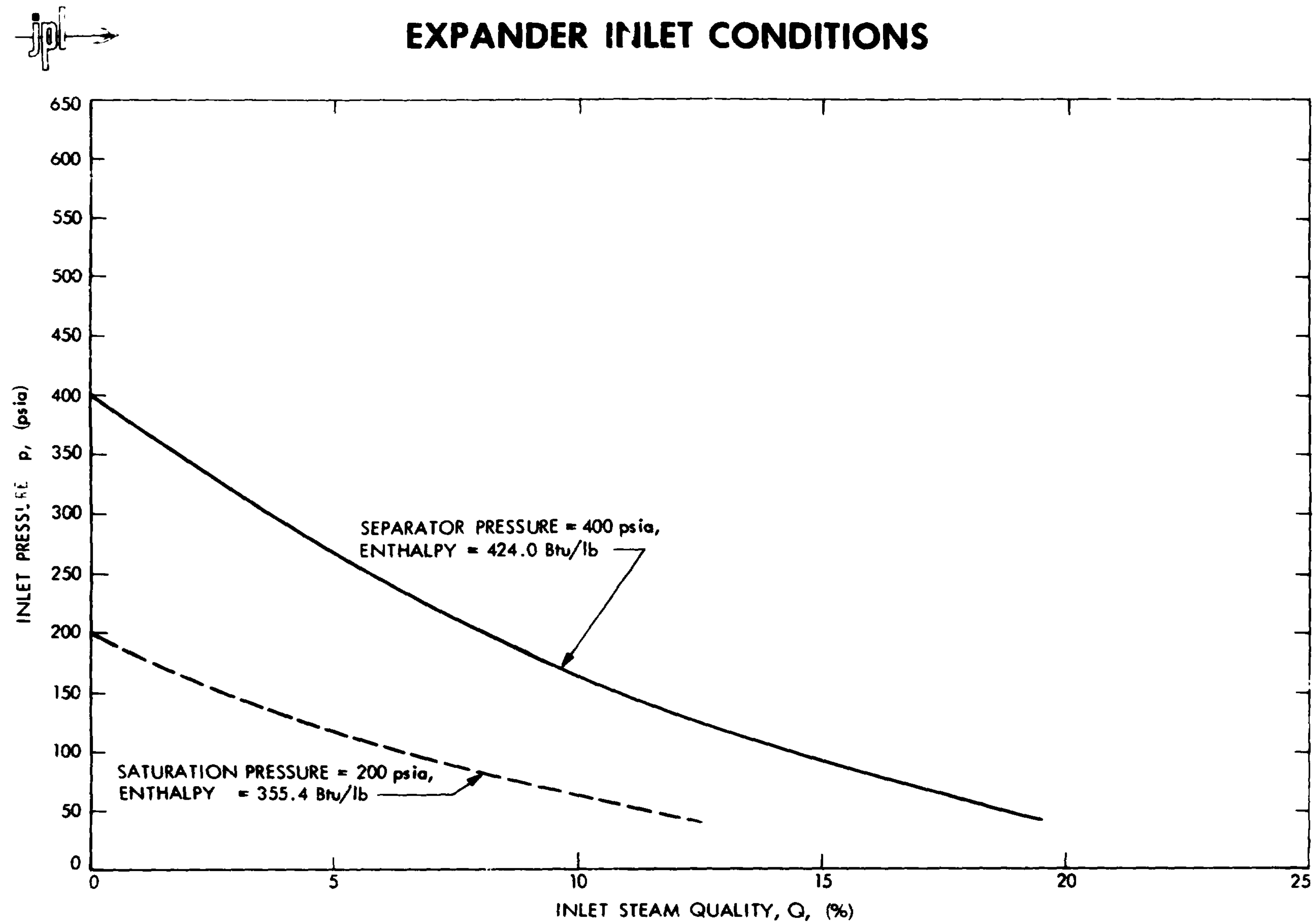

Figure 5-5. Expander Inlet Conditions for Liquid Feed from Separator

5. Process Number 5

In Process No. 5 (Figure 5-6) exhaust from the expander at atmospheric pressure flows to a waste tank where the vapor is vented to the atmosphere. Liquid flows by gravity to a pump for repressurization so that the waste water can be injected into the disposal line from the separator downstream from the point at which it was taken for use by the expander. This pressurized waste water provides a supply of low temperature waste water (approximately 200°F) which can be injected in small amounts into the feedline to the expander, at a suitable distance upstream from the orifice meter, to lower the temperature of the feed stream and ensure against flashing in the orifice. For the Well 54-3 installation, the feed pipe to the expander rose in elevation 18 feet. This presented the likelihood that flashing would occur in the pipe before the pressure control valve because of the combined effects of pipe loss and elevation gain. By increasing the recycled waste water flow it is possible to lower the enthalpy of the feed stream sufficiently to prevent flashing before the pressure control valve. This possibility soon led to the realization that the amount of recycled water could be increased as desired to degrade the feed enthalpy to any suitable value between the enthalpies of the separator liquid and the waste water stream. The implementation of this concept is shown in Figure 5-6 as Process No. 5. In this Project, fluid feed to the HSE, which has been cooled into the compressed liquid region, is reported as having a negative quality Q, with the absolute value indicating the amount of subcooling in °F.

6. Process Number 6

If vapor from the separator in Figure 5-6 is fed to the expander in controlled amounts along with the liquid, the operating conditions to the right of the curve of Figure 5-5 become available. This is accomplished by Process No. 6 (Figure 5-7). Process No. 6 requires the addition of the steam line, a flow meter and a flow control valve to the configuration of Process No. 5 at corresponding added cost. The flowrate $\dot{m}$ and the inlet enthalpy h_1 of the efficiency equation are then calculated by a material and energy balance with the combining streams. Because this process is the one actually used for the testing in Utah, it is discussed in more detail below. Relevant details of Process No. 5 apply.

Figure 5-7 shows schematically how the JPL expander test facility was integrated into the Phillips' FTF. This integration is also shown in Figure 5-8 which is approximately to scale and more complete. It shows that there were actually two waste tanks in series and two waste pumps in parallel. The process parameters with the subscripts in Figure 5-7 and 5-8 were measured by the JPL data system.

Except where noted, 6-inch diameter pipe was used throughout most of the JPL expander test facility. Exceptions include a 24-inch diameter exhaust pipe from the expander to the first waste tank, 10-inch diameter pipe for the wastewater from the tanks to the pumps, and 4-inch diameter meter runs for the vortex-shedding flow meters in the pump discharge system.

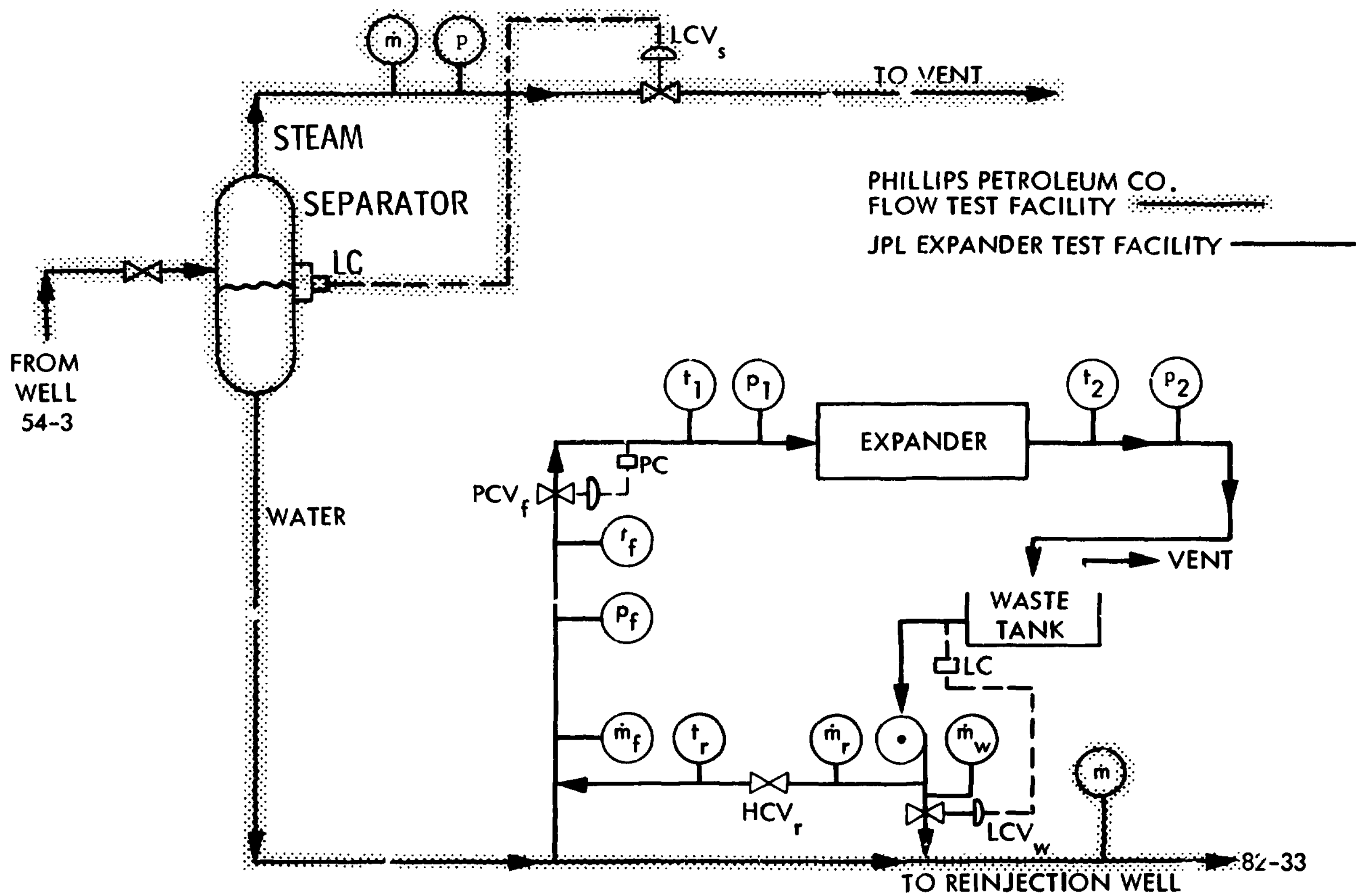

Figure 5-6. Process No. 5

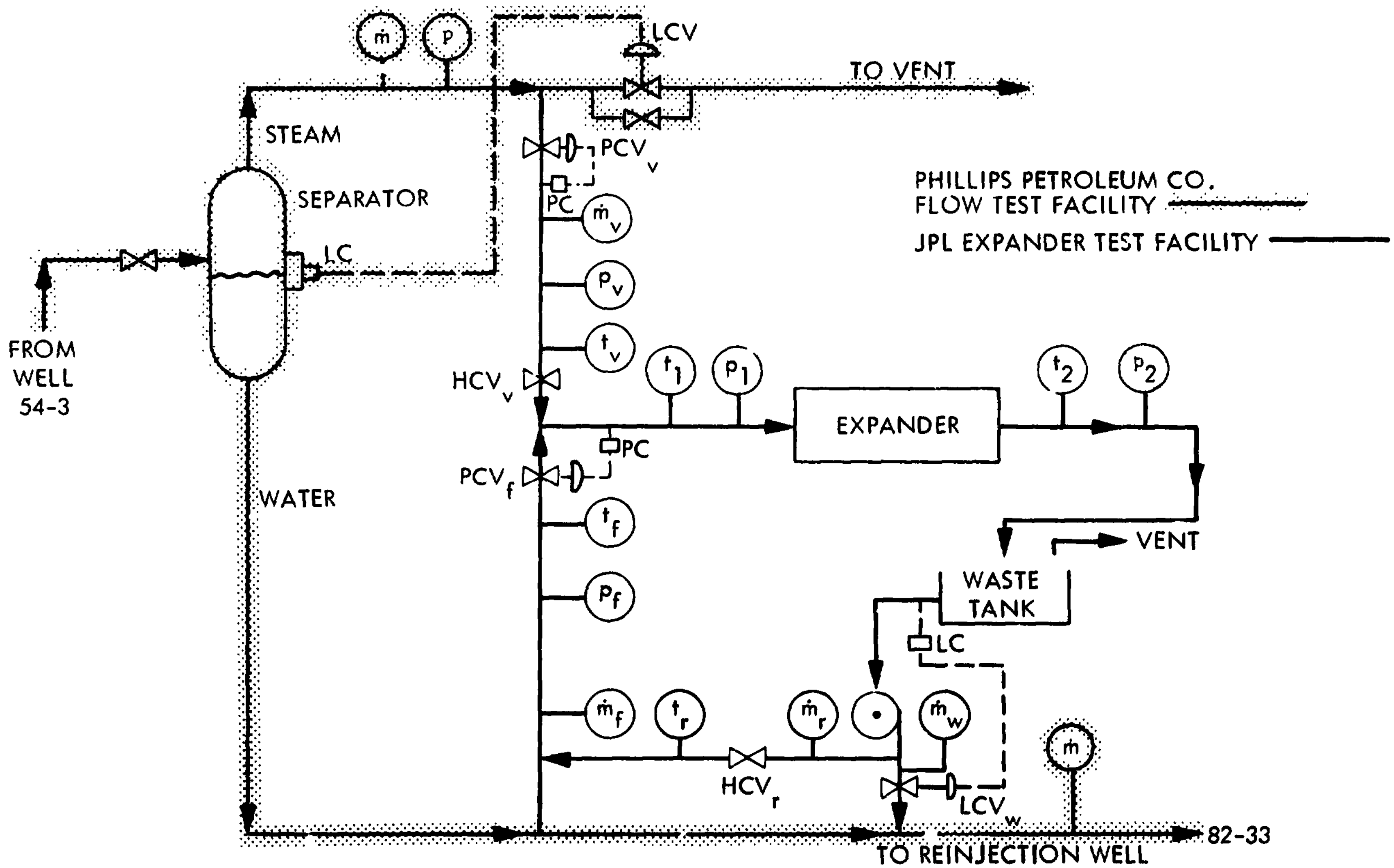

Figure 5-7. Process No. 6

SITE SCHEMATIC

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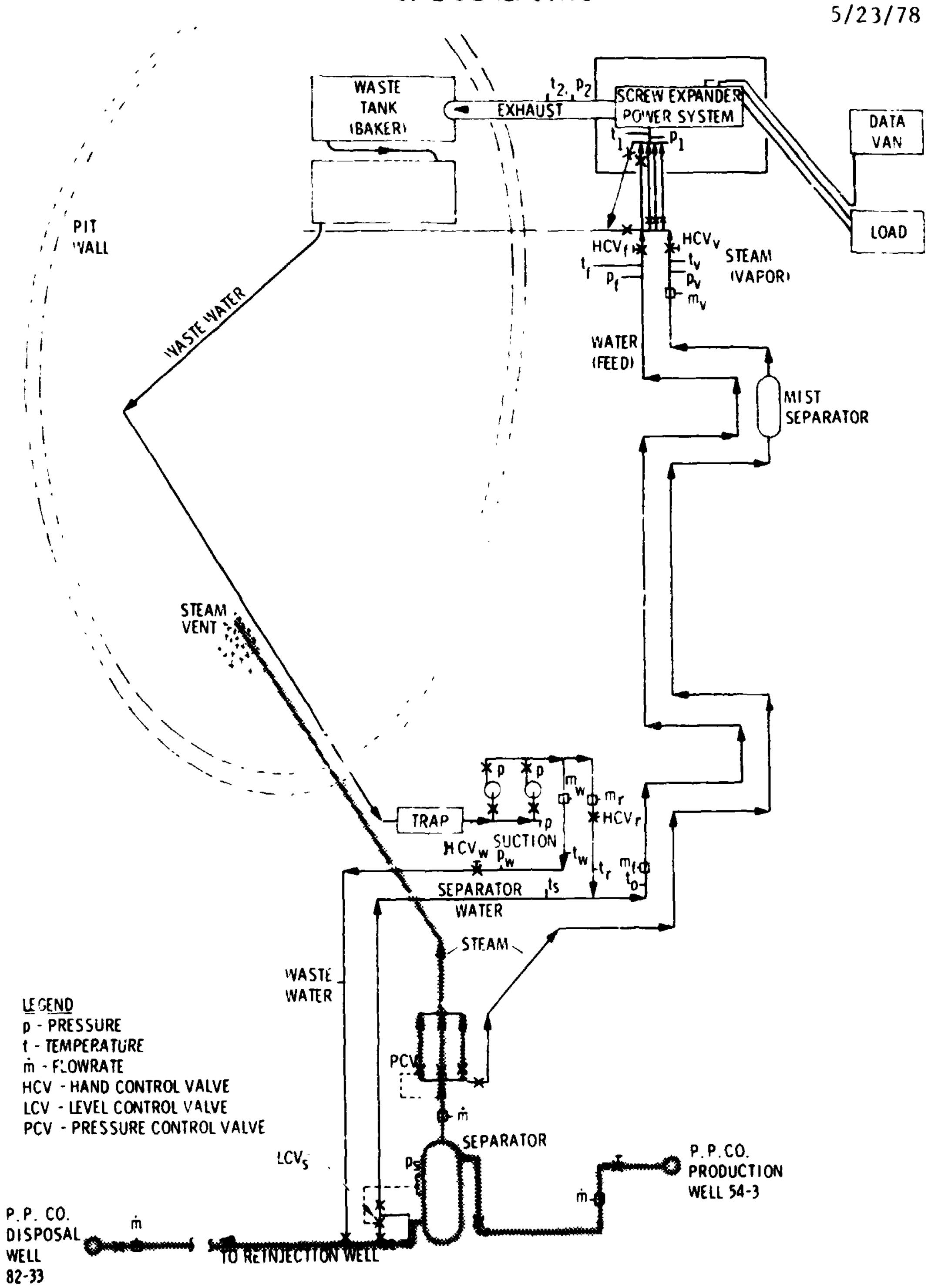

Figure 5-8. Site Schematic

As seen in an aerial view (Figure 5-9) and as discussed earlier, testing at Well 54-3 with the FTF required that the expander be installed above and at a considerable distance from the Well to allow the HSE to discharge into the existing pit which was up-slope from the well. The water feed pipe from the FTF to the point of mixing was 470- feet long and rose 18 feet in elevation; the steam pipe length was 399 feet and rose the same amount. Some of this rise can be seen in Figures 5-10 and 5-11.

Accurate test results require accurate measurement of the flowrate and the state of both feed streams at the point of mixing. Both stream flows $\dot{m}_f$ and $\dot{m}_v$ were measured by orifice meters made to ASME standards (see Appendix J). (Senior Daniels meter runs were used to facilitate changing the orifice plates on line, as shown in Figure 5-12.) As discussed under Process No. 4, the water meter run was placed at a low elevation with respect to the separator to prevent flashing in the meter. Provision was made to inject pressurized water from the expander exhaust upstream from the meter to ensure that flashing did not occur in the meter or in the pipe as it gained in elevation between the meter and the control valve at the end of the water pipe. As a further deterrent to flashing in the water orifice meter, heat loss from the pipe upstream from the meter was encouraged by running the pipe uninsulated part of the distance -- approximately 116 feet, thus also saving money. The temperature t_s of the supply water from the separator, the temperature t_r of the recycled water, and the temperature t_o and flowrate $\dot{m}_f$ of the combined stream through the orifice meter were measured; the recycled water flow rate $\dot{m}_r$ was also measured by a vortex-shedding meter (see Figure 5-13). These measurements permitted checking either flow measurement against a calculated value, or calculating a flowrate if one meter was out of range. Recycled flow rates less than 15,000 lb/h were calculated. The points of measurement are shown in Figure 5-8. This method of monitoring meter accuracy requires very accurate measurement of t_s and t_o of the main stream. Spare thermal wells were installed to permit adding differential temperature measuring equipment had it been considered necessary; it was not. To improve the accuracy of measurement of t_o, mixing of the supply and recycled streams was aided by inserting a passive mixer (6-element Ross Model LPD) in the pipe, just downstream from the point of mixing, during the preparations for the 1979 tests. The water supply pipe and the recycle pipe were thermally insulated upstream from the points of temperature measurement for a distance greater than the mixing length of the pipes. This insulation was then continued all the way to the expander base so that the temperature measurement of the feed stream t_f near the end of the water pipe would not be disturbed by heat loss from the pipe downstream from t_o. In addition, the close agreement between temperatures t_o and t_f under steady-state operation was very informative regarding the status of the process and the data acquisition system.

Precautions must be taken in determining the flow rate $\dot{m}_v$ and enthalpy h_v of the vapor stream because the vapor is not pure dry steam. Even if the vapor leaving the FTF separator is dry, it will lose heat to the pipe and become wet. Suspended water droplets can flash in the flow meter to cause an erroneous reading, and gaseous impurities typically found in geothermal fluids complicate the determination of both flow and enthalpy. Gas analysis and corrections are necessary. In the process installation, an efficient separator, or demister, followed closely by a throttling valve, PCV_v, was installed upstream from the

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Figure 5-9. Aerial View of Test Site During Installation

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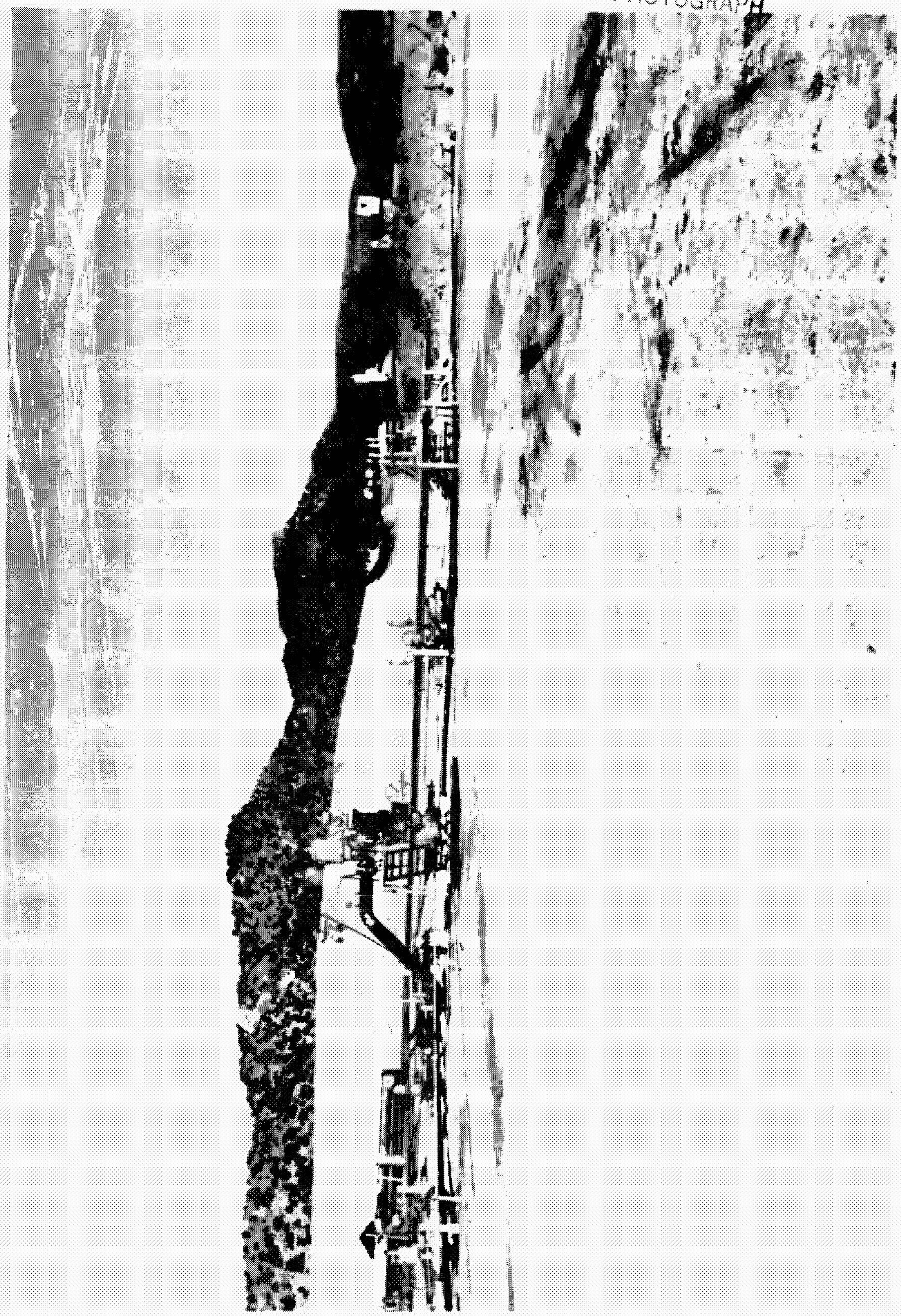

Figure 5-10. Site View Showing Elevation Changes

Figure 5-11. Site View Showing Piping Rise

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Figure 5-12. Orifice Meter in Steam Line

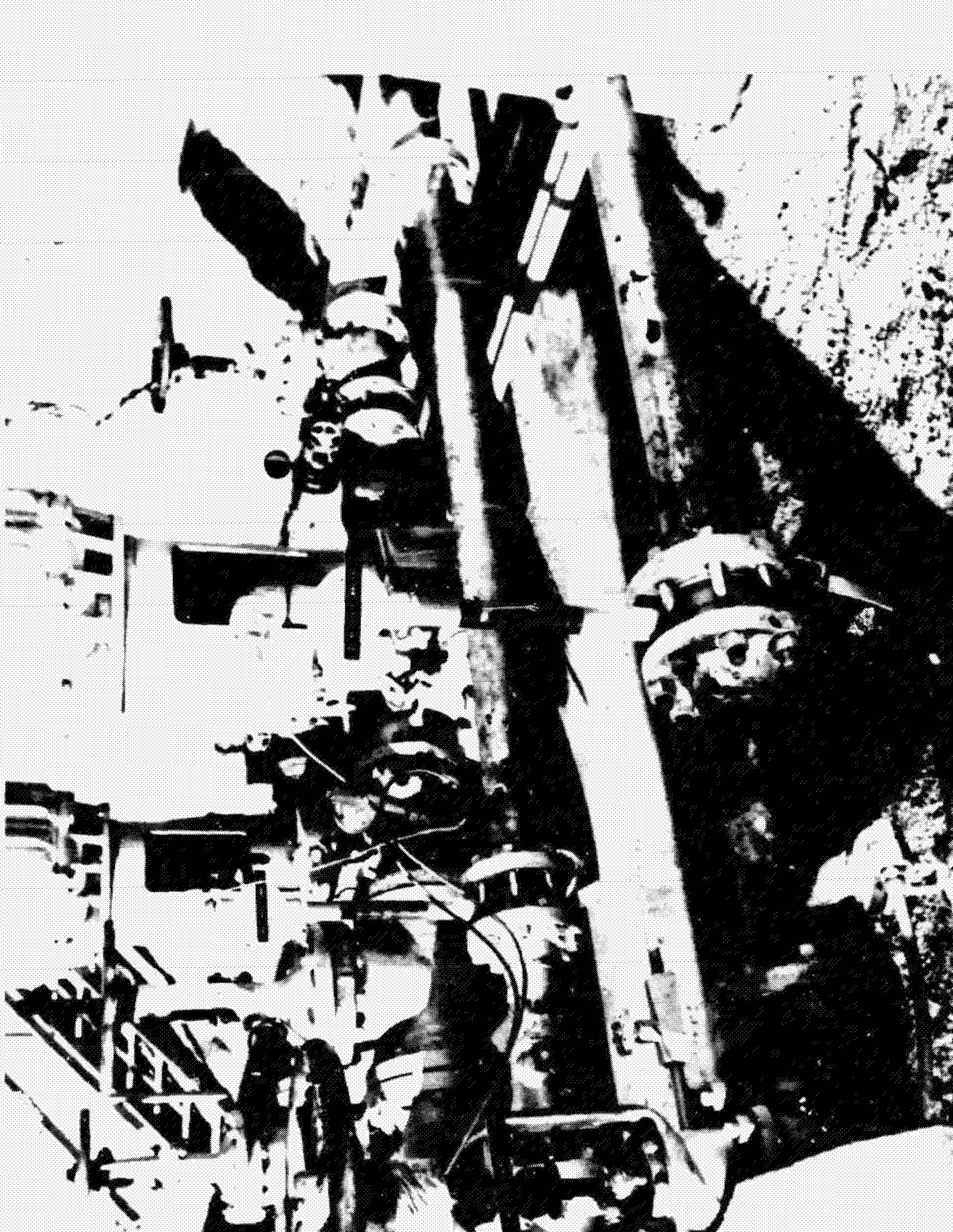

Figure 5-13. Recycle Pipe, Waste Pipe and Pumps (Pit Wall in Background)

orifice meter to ensure that the vapor stream to be measured was dry. The demister, with a liquid level sight glass, is shown installed in the steam line in Figure 5-14, photographed after the throttling valve was removed as discussed below. The demister and all steam pipes upstream were uninsulated while the pipe downstream was insulated with the following benefits: (1) the cost of insulating 332 feet of 6-inch pipe was saved; (2) the wetted pipe wall in the uninsulated pipe served as a scrubber for entrained salt spray if any existed; and (3) heat loss from the vapor leaving the demister was minimized so that the vapor would remain dry past the points of measurement of $\dot{m}_v$, t_v and p_v. The omission of the insulation upstream from the demister and the resulting cost savings were feasible because the steam was a waste product being vented from the FTF. Condensate was removed from the demister and from two low points in the steam pipe by thermodynamic traps.

In actual operation, the measurements of t_v and p_v showed that there was sufficient throttling in the mesh in the demister so that the throttling valve PCV_v was not necessary and the valve was left fully open. This superheat valve was later moved on May 17, 1978, to become the separator level control valve LCV_s for the duration of the 1978 operations (see Figures 4-3 and 5-8). The controller for valve PCV_v was used to convert the former level control valve, LCV (see Figures 4-1, 4-2 and 5-7), to a separator pressure control valve, PCV_s (see Figure 5-8), for the remaining 1978 and 1979 operations. The LCV_s was a globe valve selected for steam service which tended to scale in brine service. For the 1979 operation, Phillips replaced the globe valve with a correctly sized eccentric disc (butterfly) valve which was placed in a more suitable location in the main brine disposal line. This method of controlling the separator level with water, and the pressure with steam, gave a separator stability which made the testing of the HSE easy by comparison and reduced the required size of the test crew.

With the precautions discussed above, to ensure that the feed streams of liquid and vapor were single-phase, the thermodynamic state of the fluids was determined by the measurement of temperature and pressure. These measurements were made near the end of the feed lines, just before mixing, p_f and t_f for the liquid, and p_v and t_v for the vapor (see Figures 5-7 and 5-8). In designing the process, it was assumed that flashing would occur across PCV_f for much of the operation, as this valve controlled the supply pressure to the expander, and that phase separation would be minimized by allowing this flashed fluid to flow in a straight line to the HSE power plant. The steam was piped into the flashing zone immediately downstream from the valve for mixing to take place. No other mixing was planned. In practice, this arrangement proved fully satisfactory for certain operating conditions, but not for all. At low load and low feed quality, the flowrate in the 6-inch pipe to the power plant was not sufficient to prevent separation, leading to slugging onboard. Operating instability of the power plant resulted. This problem was caused in part by two-phase flow occurring in the pipe from the FTF separator because of unsuitable level control in the separator part of the time prior to the installation of the LCV_s. This was exacerbated by hunting caused by independent automatic control of the pressure-regulating valve PCV_f and the speed governor on the HSE power plant. Several modifications were made in the process piping at various times.

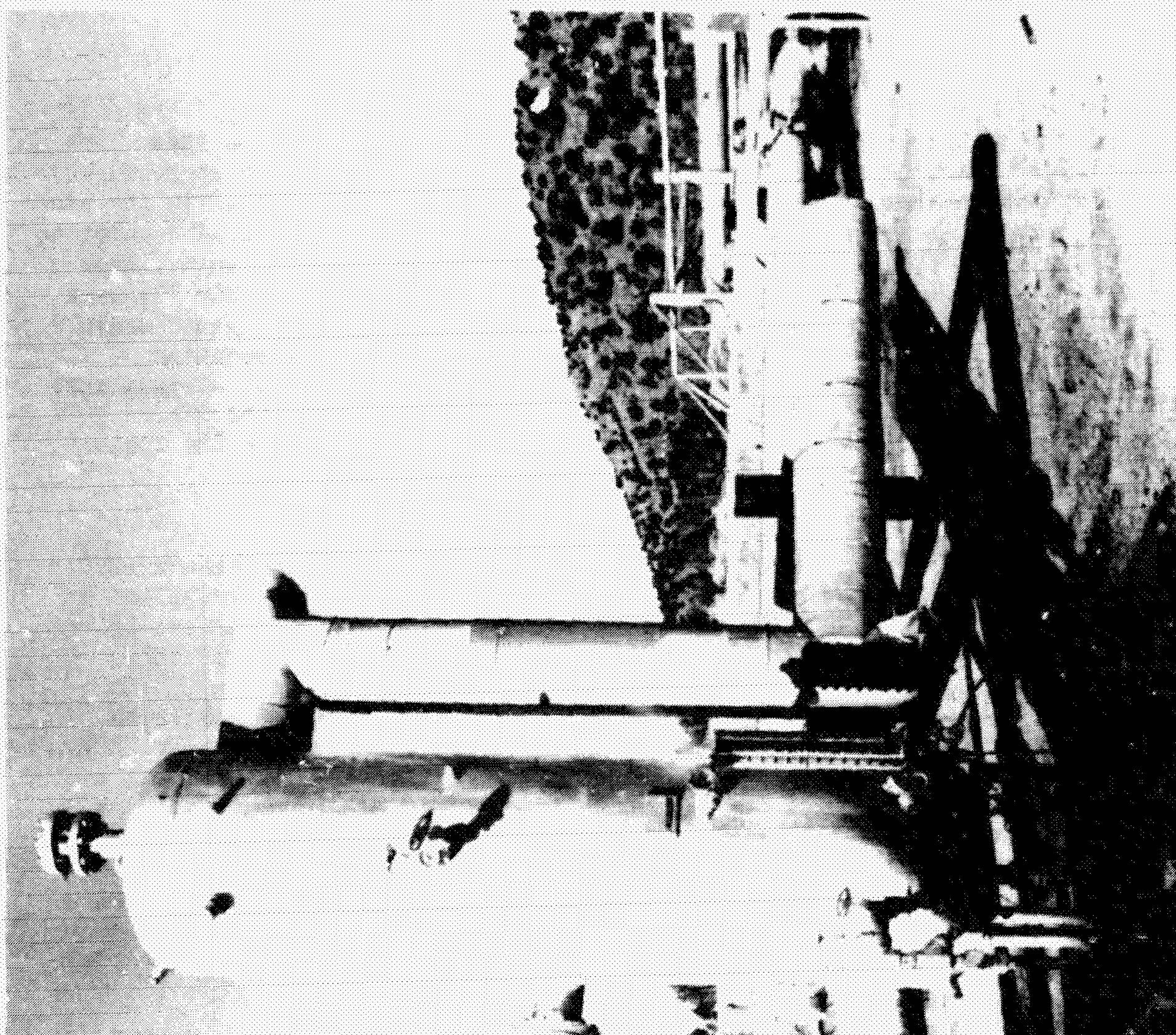

Figure 5-14. Demister Installed in Steam Line: 1979

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First, the PCV_f valve was operated in the manual control mode to become hand control valve HCV_f. This was an eccentric disc (butterfly) valve which suffered damage to its pneumatic/manual operator during the course of the 1978 operations. It was then modified for simple hand-lever operation of its rotary shaft, and thus became a very effective process control tool in the hand of a skilled operator. The effectiveness of this operation was greatly enhanced by good radio communication among the operating locations of this valve, the power plant and the Data Van. Second, the single, 6-inch feed pipe to the power plant was replaced by smaller pipes, each with a gate valve, manifolded together in parallel (see Figure 5-8) so that by selection of feed pipe size or sizes, the velocity could be kept high and the fluid separation minimized. The final configuration in 1978 consisted of four pipes in parallel, one 4-inch, two 2-inch and one 1-inch. For the 1979 testing, the parallel feed pipe arrangement was replaced with two feed spools, one 6-inch and one 4-inch, each equipped with a 6-element passive mixer (Ross Model LPD), with the spools to be used interchangeably according to the feed conditions of flowrate and steam fraction.

The installation and operation of the level control valve LCV_w in the waste water line to control the level in the twin waste tanks (see Figures 5-8 and 5-15) was satisfactory from the standpoint of process control but not from that of testing the HSE. There was sufficient disturbance of the level of the water in the second waste tank, where the level controller was mounted, because of agitation in the first tank, where the waste water was received, to cause some hunting in the controller and valve. This caused the load on the HSE to vary during the test because the disposal pump motors were driven by the HSE power plant. Thus, it was better to operate the level control valve manually and allow the waste level in the tanks to change. Process control was facilitated by adding a waste level transducer L_w to the data system, and by calculating the rate of change of level in the tanks with the computer operating program using a material balance. The comparision of the calculated and observed change in level served as a continual check on the validity of all of the process calculations since all of the flow measurements, as well as the calculated flashing within the HSE, entered into the material balance. Agreement was excellent throughout the tests. The level control valve installed in 1978 was a globe type, and because it exhibited sticking from scale deposits during operation, it was replaced with an eccentric disk (butterfly) type with hand-lever control for the 1979 operation. An extension was installed on the hand-lever at the time of valve installation to facilitate fine control.

Water from the waste tanks flowed by gravity through the 10-inch pipe to the two five-stage centrifuge pumps which were installed in parallel as shown in Figure 5-8. Part of the 10-inch pipe was existing pipe used for testing Well 54-3 prior to 1978. Early in the testing of the HSE, protective basket screens installed in the feed lines to the pumps plugged with flakes of scale and rust believed to come from the old pipe, thus starving the pumps and interfering with the testing. Repeated cleaning of the screens did not solve the problem, and it became necessary to replace as much of the old pipe as possible, leaving in service only that section which passed through the pit wall. During the replacement, the inner wall of the the remaining old section was scraped with a special tool fabricated for the purpose. Replacement of the old pipe did not

Figure 5-15. Waste Tanks in Operation

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solve the problem completely so a section of 24-inch pipe, 11-feet long, was spliced into the line to serve as a solids trap (Figure 5-16). In addition, provision was made for back-flushing the screens one at a time while they were in place, using water from the other pump discharge, to reduce the need to remove the screens for cleaning. The blockage material initially consisted of mostly hard dark flakes which eventually were replaced by fewer light-colored flakes of scale which was soft and probably newly formed. The density was low enough so that the trap did not work very well. During the brief testing in 1979, the scale flakes felt soft enough to pulverize in passing through the pumps, so the screens were removed for expediency with no known deleterious effects.

A temporary process modification, not shown in either process schematic was made and used in 1978 to permit testing the HSE at elevated back press[illegible] The modification consisted of a simple back pressure plate, with adjustabl[illegible] [illegible]ice, installed in a flange in the expander exhaust pipe. The device served [illegible] valve to control the back pressure (Figures 5-17 and 5-18). A slide gate was [illegible] in with a maul or out with a jack screw to adjust the orifice. The device was used in the elevated back pressure tests in Mexico in 1980.

In preparation for the 1979 testing, a modification was made to cool the water from the separator to prevent flashing in the orifice meter, or in the pipe rise to the control valve HCV_f. A heat exchanger, in the form of a water trough, was installed around a 26-foot length of the uninsulated part of the feed water pipe and can be seen in Figure 5-19. The purpose was to be able to accomplish the required temperature suppression of the water without the admixing of recycled water in order to eliminate the possibility that the recylced water, with its precipitates, could interfere with the deposition of scale within the expander. The heat exchanger was not sized for all test conditions, but was designed with the idea that scale deposited under one set of circumstances, perhaps every night, would meet the needs of any test condition during the day. The cooling water was water in excess of the 4 gpm needed for the shaft seals, produced from a steam condenser designed for this combined purpose.

Water for flushing the shaft seal assemblies was not needed until the testing in 1979. The trucking of water to the site was considered, but the water must be of feed quality suitable for a low pressure industrial boiler, and neither a truck nor water of this quality were readily available. The availability of surplus steam from the FTF made the production of steam condensate appear practical for this purpose. Therefore, steam was withdrawn from near the bottom of the demister and passed at nearly FTF pressure through a heat exchanger consisting of lengths of 1-inch pipe assembled near the bottom of the first waste tank. Since the water in the exhaust of the HSE entered the waste tank at the atmospheric boiling temperature of the test site altitude, approximately 200°F at 6115 feet, the temperature differential was substantial. The condensate then passed through an air-cooled heat exchanger of 1/2-inch pipe ass[illegible]bled along the east edge of the pit, to drop the temperature to 160°F or less (Figure 5-20). The condensate was purged of noncondensables as it left the waste tank. A line from the west end of the air exchanger assembly conveyed a portion of the water through a hand valve into the trough-type heat exchanger installed on the water pipe from the FTF, as described earlier. Water for flushing the seals passed

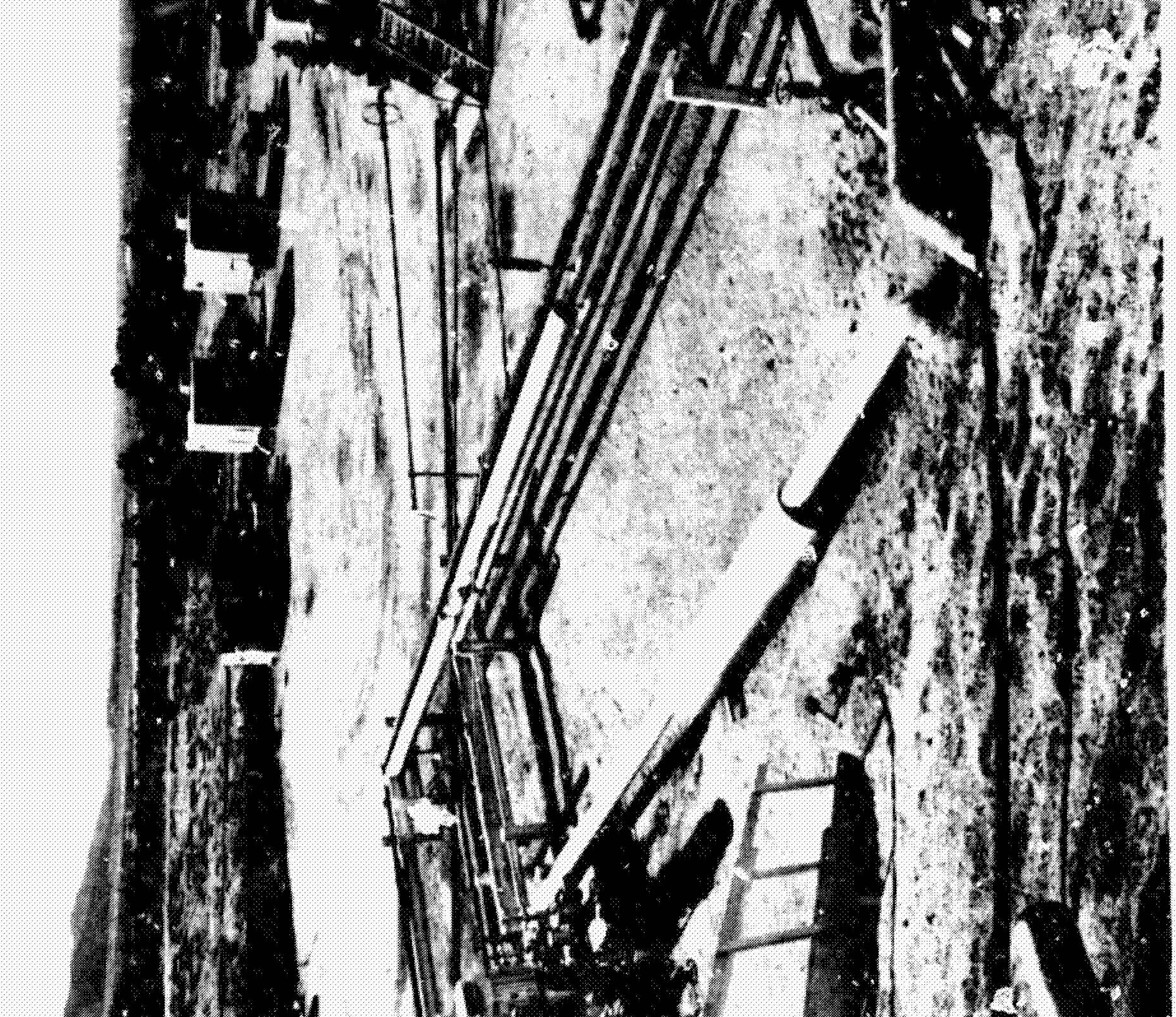

Figure 5-16. Part of Process Installation Seen from Pit Wall

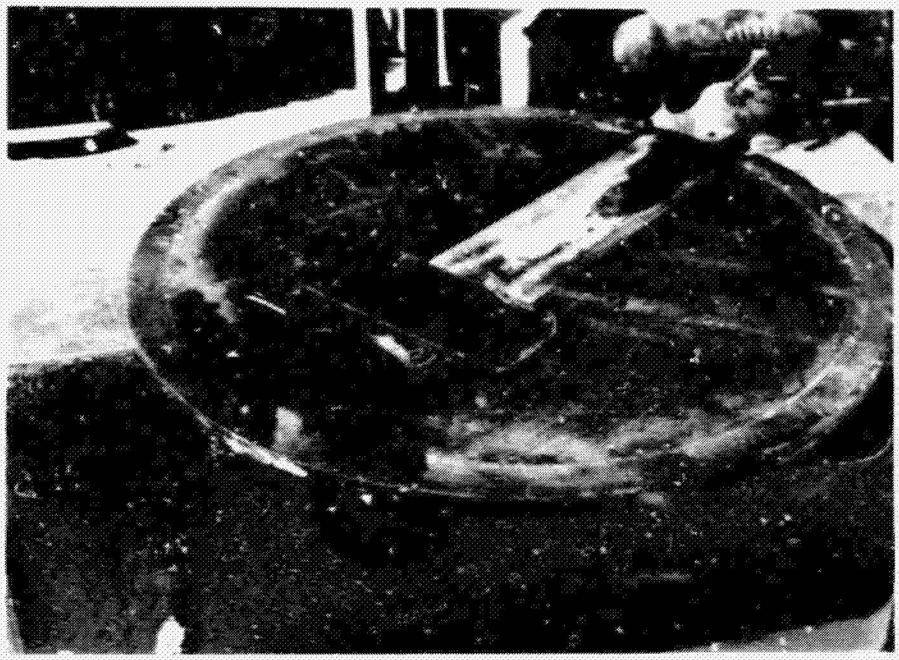

Figure 5-17. Back Pressure Plate

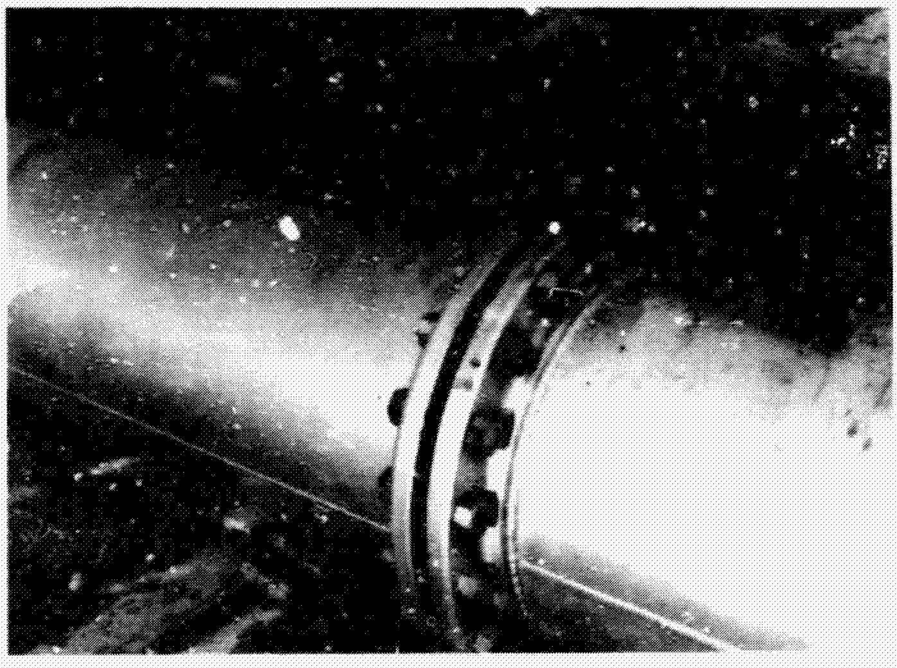

Figure 5-18. Back Pressure Plate, Installed

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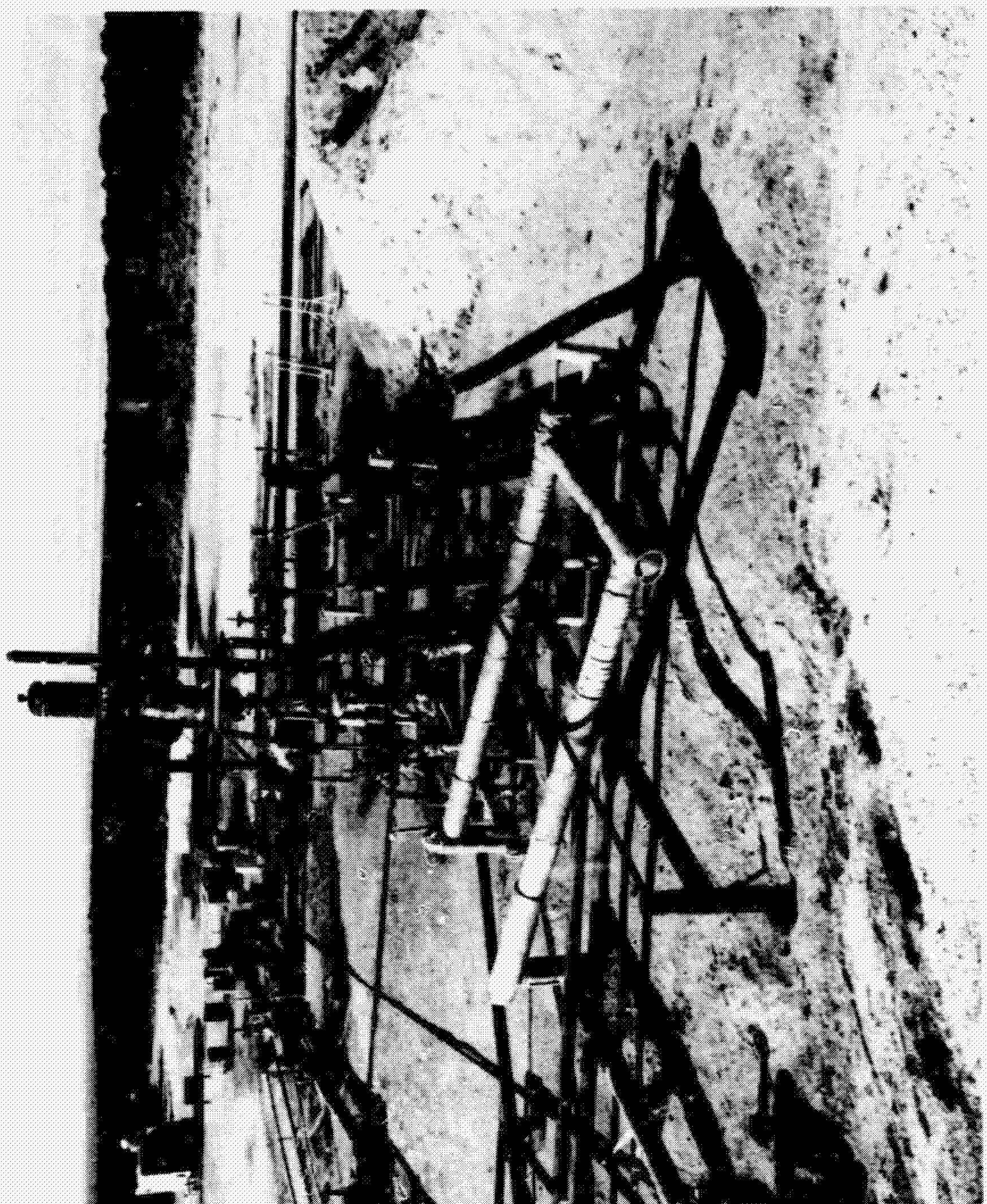

Figure 5-19. Part of FTF Seen from Pit Wall

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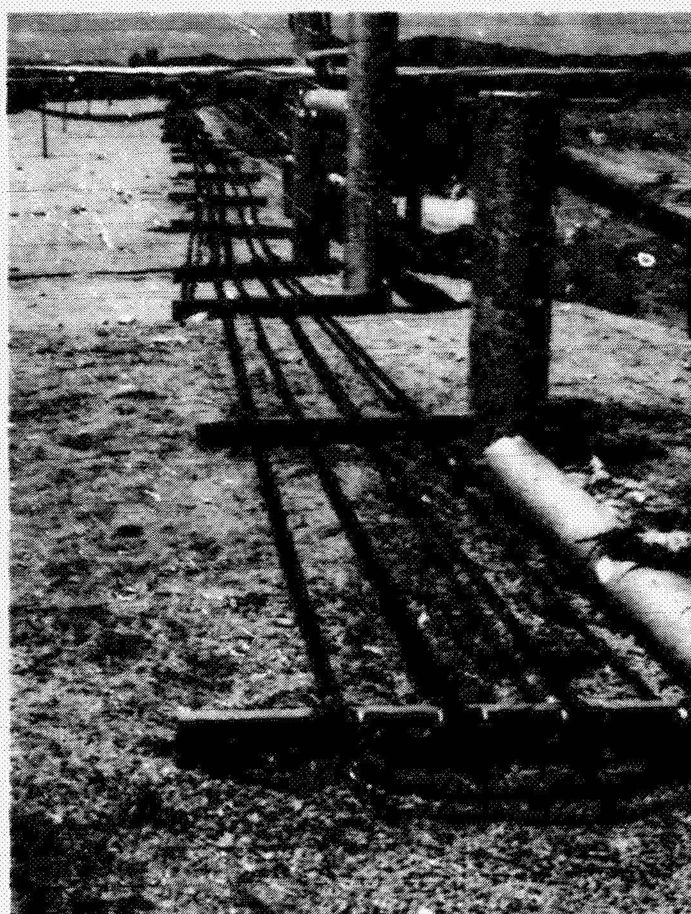

Figure 5-20. Heat Exchanger for Condensate

from the air-cooled heat exchanger into a 400-gallon holding tank through a float valve. Inspection of the water from the holding tank revealed that it was badly contaminated, possibly by corrosion products from the pipe. Experiments conducted at the site showed that aeration of the water along with vigorous agitation with bentonite yielded clear, colorless water of satisfactory quality upon standing. The aeration evidently oxidized the impurities which were then flocculated and removed by the bentonite. The aeration and flocculation were done in the holding tank, and the settling was done in a 20,000-gallon tank loaned to this Project by the Halliburton Company (Halliburton). Treated water from the Halliburton tank was then passed through a 25-micron filter and sent to the seal-metering pump assembly.

SECTION VI

FIELD TEST OPERATIONS

A. PRE-FIELD TEST OPERATIONS: 1977

After the fabrication of the 1-MW HSE power plant was completed in August 1977, it was necessary to subject it to acceptance testing by HPC and JPL. The purpose was to check and adjust the static and dynamic performance of the power plant and its components and subsystems, and to interface with test support equipment provided by JPL. The subsystems included the safety shutdown system, designed to protect the power plant against equipment malfunction, the hydraulic and governor speed control system, the lube oil system, the greasing system, and all the local and remote power plant controls such as start enable key switch, governor or frequency adjustment, voltage adjustment, normal stop, and emergency stop. For this purpose, an acceptance and interface test procedure and check list was prepared by JPL in consultation with HPC. One version is presented in Appendix K. The acceptance testing also examined the power plant for vibration and alignment of the drive train.

The possibility was reviewed of moving the HSE power plant from its place of fabrication in Mission Viejo, California, to JPL in Pasadena, California, for acceptance testing with air from the JPL wind tunnel. This proposal was rejected in favor of testing in Mission Viejo using air from rented compressors. Therefore, the Data Van was moved to Mission Viejo and installed for the tests. The load bank was not included in these tests because it was recognized that it would not be practical to generate sufficient electrical power from compressed air. Instead, the load bank was fully tested at JPL. This proved advantageous because corrections were required by the manufacturer for weather protection of some electrical components, matching of fan direction, and loose control wires. All airflow and thermal protection devices were checked, and adjusted, if necessary. Satisfactory operation resulted.

Static and dynamic testing of the HSE power plant were conducted in sequence, with the static testing being conducted a few days in advance to be sure the power plant was ready for the more cumbersome dynamic testing. Dynamic acceptance testing of the HSE power plant was necessary five times, once in August, once in September, twice in October, and once in December. The amount of air required for the tests was large, and required as many as seven large engine-driven compressors. These engine-driven compressors are noisy and tend to be unwelcome in a normally quiet industrial park. The first tests were conducted on Thursdays to make Friday a carry-over day. Warnings and ear protection were provided for test participants and neighbors. The fifth test was scheduled for a Sunday when most people would be away from the nearby business locations.

The first dynamic test, on August 18, provided a good check of the equipment, and a good check of the test procedures. Minor adjustments or revisions were made in both the equipment and test procedures. The testing was approached cautiously and proceeded well for about 15 minutes, at which time the speed control failed, and the test was terminated. The problem was correctly diagnosed as a damaged governor. The governor that failed was installed on the bell housing on the high pressure end of the HSE, and was driven by a spline mated to the female rotor shaft with very little clearance. The shaft sizes, bearings, bearing type, and bearing clearances of the governor and the rotor differ greatly. It was concluded that a new governor, installed with clearances in the spline to allow for the possible relative displacement of the two shafts, would solve the problem, and it did.

During the second test, on September 14, the rotation of the power train was very smooth and free of vibration, although a delicate tachometer presented an erratic display indicating the need for a cushion mount. All electrical systems appeared to perform well, including power, control and instrumentation. The fault detection system, monitored by the computer in the Data Van, worked well, but JPL saw the need for a fault status annunciation panel on the power plant. The second test was terminated prematurely because of a problem with the shaft seal assembly on the male rotor at the high pressure end. The shaft seals were pressurized with oil through check valves. It was inferred that friction heating caused thermal expansion of oil and possibly water residues trapped in the seal assembly behind the check valves, causing excessive pressurization of the seal and, as a result, excessive frictional heating. Differential thermal growth resulted, causing some seal retainers to friction-weld to the shaft sleeve. The remedy was to replace the damaged parts, to omit three redundant seals from the repaired assembly in order to decrease the frictional heating, and to provide pressure relief valves in the oil supply lines. Also, in preparation for the next test, the tachometer was cushion-mounted, and JPL fabricated and installed a 16-light annunciator panel to show the status of the fault protection shutdown system.

The third test, on October 20, was terminated because of rotor-to-rotor contact in the HSE, evidently caused by incorrect adjustment of the timing gears after the installation of the repaired shaft seal assembly. The rotors were scarred, but the damage was minor. The damaged surfaces were polished and the rotors were re-timed in preparation for the next test.

The fourth test, on October 27, was terminated after approximately 1 hour and 45 mintues by another shaft seal assembly failure. This time the failure was at the low pressure end of the male rotor. The failure and damage were similar to the previous failure on the high pressure end of the male rotor. The failure occurred just after operation in overspeed condition, established for setting the overspeed switch, when surface speeds and friction heating would be greatest. As in the previous test, the seals were operated with abnormally low oil pressure to minimize heating during run-in. An analysis indicated that differential thermal growth caused interference between parts of the seal assembly housing and the sleeve on the rotor shaft. The remedy was to replace the damaged parts, omit the redundant seals, and increase critical clearances in all of the seal assemblies.

The fifth and final test was performed successfully on December 4. The test was continued for 4 hours and 15 minutes with no unfavorable incident.

After the successful acceptance test, the Data Van was disconnected from the power plant and returned to JPL. The HSE was officially delivered to JPL in-place. At that time the electrical distribution panel was modified to provide 480-Volt, 100-amp service for the two waste disposal pump motors needed for the process installation in Utah. This reflected the change in plans for testing with Well 54-3 and Process No. 6 rather than Well 13-10 and Process No. 4, and the resolution of how the waste disposal would be accomplished.

B. FIELD TEST OPERATIONS: 1978

1. Advance Preparations

Essential to the field operations in 1978 were the design and fabrication of the test array -- HSE power plant, load bank, and Data Van (including the data system) -- the selection of the test site, contracting with Phillips for its use and assistance with the test process installation, the design of the test process, the specification and procurement of the process piping and associated equipment, the contracting for the leasing and delivery of the waste tanks, the contracting with AAA Welding, Co. for the test process installation, the advance site layout work and preparations, and the planning and approvals associated with all of the above. All of these things were accomplished before the end of 1977.

2. Test Preparations

The installation of the equipment and other test preparations at the site in 1978 began with two serious constraints -- weather and schedule. The site was at an altitude of 6100 feet, on the west side of the Mineral Mountains in the high western desert of Utah. The record mean temperatures for January and February based on the 65-year average at the nearby Milford station, which is 1072 feet below the test site, were 25.4°F and 32.0°F, respectively. Average lows were 12.7°F and 19.3°F, often reaching to -28°F. Fortunately, the winter of 1977-1978 was unusually mild, with few storms, and although working conditions were severe they were far from impossible. Appropriate clothing, purchased in advance on the basis of expected conditions, proved highly beneficial. A climatological summary for Milford, about 15 miles away, is presented in Appendix L.

The installation and test schedule of the HSE was tied inexorably to the test schedule of the FTF. The purpose of the FTF test in 1978 was to provide Phillips with well production and reservoir pressure data, while perturbing the reservoir until the end of March, to thus complete a 6-month flow test which was started by Phillips in October 1977 in order to evaluate the reservoir. This schedule made the 4-month delay required for the HSE power plant acceptance test very serious. It is obvious that this Project would not have been well served by a test installation which was not completed until after the production well was shut-in. Therefore, once a start of the installation was possible, it proceeded on a high priority basis using all of the daylight hours, weekends included and weather permitting, until it was completed. In general, the work went exceedingly well, and testing was ready to begin on March 16.

(The HPC contract with JPL specified that HPC deliver an operating manual, specifications and a final report with the power plant. The urgent need for HPC to assist JPL with the installation and test preparation at the site reduced the priority of the delivery of these documents. Part of the rationale for postponing their delivery was that they could be updated to include field experience, i.e., equipment improvements in the manual and specifications, and plant operation experience in the final report.)

The test preparations and testing were greatly aided by including at the test site lodging and shop facilities for the JPL and HPC operating personnel. JPL made use of a motor home to serve as a project field office, a meeting place, a visitors center, and lodging for the JPL principal investigator-technical manager of this Project. HPC installed a mobile home to serve the corresponding needs of the HPC chief engineer and staff, and provided a very well-equipped shop trailer. These facilities saved many round trips (an hour or more) to Milford or beyond, and greatly aided the personnel efficiency of the field operations.

3. Testing: 1978

The testing in 1978 was affected by several major factors, namely, the operating performance and test schedule of the FTF, feed stability to the HSE, and equipment failures.

a. Process Factors. The test specifications for the FTF required operating the separator at 385 psig, and at a specified flow, for 6 months, to draw down the reservoir for its evaluation. The FTF included disposal Well 82-33, located 1-1/4 miles from production Well 54-3, and at a 300-foot lower elevation. During the period of installation, test preparation, and early testing of the HSE, disposal Well 82-33 did not accept the flow specified for the FTF. This produced one favorable and one unfavorable consequence for testing the HSE. The favorable consequence was that the resevoir draw down was below specification for the specified schedule, and therefore Phillips extended the FTF test schedule through May. This schedule extension made the testing of the HSE in 1978 possible. The unfavorable consequence was that the lower flow in the FTF made it necessary for Phillips to modify the steam flow control hardware to be able to provide level control in the separator. The steam flow control hardware had been designed for the specified flow. The modification provided stable control of the FTF when it was operating alone, but it was no longer insensitive to disturbances such as those caused by testing the HSE, as it had been before. (See Section IV.A.2.c., Pressure Stability of the Test Fluid Supply.)

This loss of level control stability was not recognized during the early testing of the HSE, possibly because the attention of the small test crew was usually directed elsewhere, and loss of liquid level in the separator often resulted. The consequence was two-phase flow in the liquid line to the HSE, unstable flow measurement, unstable flow control, and unstable HSE operation. This occurred during the time when adjustments to the governor system were being made, and when the operation of the governor and automatic PCV_f valve were interfering with one another.

Several corrective measures were taken as testing proceeded during the first few weeks. First, the PCV_f valve was put on manual control and later converted to the HCV_f valve. Second, continued improvements were made in the governor control system. Third, more attention was given to the liquid level sight glass on the separator once the problem was recognized. Fourth, an oversized feed pipe to the power plant was replaced with a parallel set of smaller size pipes in a manifold arrangement. Fifth, the separator was instrumented so that pressure p_s and level L_s could be monitored by the data system from the Data Van. Each of these corrective measures was important, but the conversion of the PCV_f valve to the HCV_f valve and the instrumenting of the separator were the most important corrections.

The instrumenting of the separator made it possible to monitor the fluid level in the separator closely and to make timely corrections in the process operations. By this time two changes had been made in the FTF by Phillips. First, the disposal Well 82-33 was perforated at a horizon where lost circulation was logged during the drilling. This solved the problem of disposal flow, and led to the second change. Second, installation of a hand control valve at the disposal well was made to restrict the flow. This flow restriction was necessary so that a satisfactory pressure and liquid level could be maintained in the separator. The importance of the hand control valve at Well 82-33 for the control of the level in the separator led to permission being granted for JPL to manipulate the hand control valve as needed during the testing of the HSE.

It is important to note that although the perforating of the disposal well increased the possible flow rate in the FTF, it did not result in meeting both flow and pressure specifications simultaneously. This may have been due to restrictions in the production well because of scale deposits. Phillips continued to operate the FTF according to the needs of the reservoir evaluation, and at the same time provided every possible accommodation of the 1978 test needs of this Project. The 1978 HSE test data are the result of an outstanding cooperative effort.

The need to coordinate the various test operations, especially the numerous manual operations (five hand-control valves, load changes, pump start and stop, etc.), made good communication very important. This was facilitated by four portable FM transceivers (walkie-talkies) borrowed from JPL, and citizen band radios (CBs) in contractor vehicles. The FM radios served at the power plant, in the Data Van and around the the HSE test process installation. Headsets were used in noisy areas. Communication with FM radios to and from the disposal well was not possible because the disposal well was shielded by a knoll near the test area. Because of this problem, CBs were used for communicating with the disposal well. Thus, an operator stationed at the separator before the L_S instrumentation was installed acted as an information relay using one FM and one CB radio. The system was clumsy, but it worked.

After the separator was instrumented, it became possible to monitor pressure changes in the separator resulting from level changes. As the FTF process control diagram shows (see Figure 4-2), a rise in level made the PCV close, causing a rise in separator pressure and forcing more liquid to flow to Well 82-33. Since a constant level in the separator was difficult to maintain during the testing of the HSE, the pressure in the separator varied. Thus, it was difficult to maintain constant pressure in the supply to the HSE. These factors, and the availability of all necessary equipment, argued in favor of changing the method of controlling liquid level and pressure in the separator (see Figures 4-3 and 5-8). With ample reservoir data in hand, Phillips acquiesced on May 17, provided the Well 54-3 shut-in period required to make the process change would be short. The change was made expeditiously, requiring the well be shut-in for only a few hours. Details of the change are discussed in Section V.A.3.f.

b. Equipment Failures. Two significant failures occurred with the HSE, both of which were a repeat of failures which occurred during the acceptance testing. The first was a governor failure which occurred during the first few minutes of field operation. Again, it resulted from inadequate compliance in the spline coupling to the expander rotor shaft which drives the governor. The failure was attributed to dimensional changes in the bell housing, on which the governor was mounted, caused by heating from the hot geothermal fluids. This was in contrast to the cooling which occurred during the acceptance testing with air. A repair of the governor, careful alignment during installation, and the use of a spline assembly with greater compliance solved the problem.

The second and the most significant equipment failure was actually another pair of failures of the shaft seal assemblies. Both seemed to occur gradually with some evidence to indicate an initial accumulation of dirt (scale) in the seals. Oil leakage increased progressively from normal to excessive amounts. The first failure in the field led to a condition of excessive oil loss, and caused cessation of testing on April 24. Attempts to re-seat the seals failed. The oil loss had reached about one barrel per hour, and a repair of the seals on the low pressure end of the male rotor was necessary. While trying to re-seat the seals, it was discovered that the pressure gauge, which had been used to set and monitor the oil pressure to the low-pressure end seals, was seriously in error. It indicated 25 psig at an actual pressure of 7 psig. As a result, the seals were protected less from the brine than was planned.

Examination of the seal assembly showed scarring on the sleeve and a split in the sleeve from end to end. The assembly was replaced, and testing was resumed on May 1. Oil leakage again became a problem, and on May 12 an air compressor was installed to inject air into the seal assemblies as a buffer so that testing could resume.

On May 30 at 12:13 a.m., on the ninth day of continuous operation, the seal assembly on the male rotor at the low pressure end began to seize, and at 12:20 a.m. finally failed catastrophically. Some assembly parts were friction-welded together, and the testing came to a halt. The friction heating melted the babbit in the adjacent bearing pads and warped the shaft. This failure occurred during an endurance run which began May 22 at 10:00 a.m. At the time of the failure, there was some warning in the form of slowing of the HSE as shown on the printed log. This slowing was misinterpreted as being caused by a gradual decrease in feed liquid availability, which had required a process adjustment a short while earlier. At that late date, no more testing could have been done if the HSE had been stopped for repair in response to the slowing, because the FTF was scheduled for shutting-in the next day. However, some of the damage could have been avoided if the warning had been properly recognized and the power plant stopped. The temperature of the adjacent bearing may have signaled incipient failure, but it was displayed only on operator demand. Only the temperature of the bearing at the high pressure end of the male rotor was displayed routinely. One of the reasons for adding a second 17-inch printer for the 1979 testing was to provide room for the routine display of all of the bearing temperatures by the operating program. In addition, the 1979 program caused the computer to signal if any bearing temperature exceeded a selected value.

A few minor random equipment failures occurred during the weeks of testing, such as a loose wire, a leaking fitting, a valve shaft pin, etc., but these were of little consequence. The hydraulic system associated with the automatic safety shutdown of the power plant exhibited a series of malfunctions usually attributable to dirt interfering with the operation of two pilot-operated solenoid valves. This malfunction interfered with plant start-up, and delayed the testing on several occasions.

The data system was nearly trouble-free throughout the test period. Erroneous values of t_0 were recorded May 1 and May 29, but the problem was self-correcting. The problem may have been caused by incipient failure of a relay in a relay card used for scanning in the multiprogrammer. This card was later replaced. On May 4 and 5, erroneous values were recorded for $\dot{m}_r$ and $\dot{m}_w$. The problems were solved by cleaning the vortex meters and improving the electrical grounds.

The most exasperating equipment problems were with the load bank which did not work, or stopped working, on 7 test days during March, April and May. This behavior either prevented testing or stopped it. The problems were caused by some of the six thermal protection devices being set too low, by a loose wire to a relay, and by wind gusts, all tripping the protective shutdown system for the load bank. The shutdown system was connected to the fault monitor in the data system as an aid to diagnosing the troubles, but the erratic behavior of the loose wire produced misleading information. The thermal protection devices were easily reset to solve that problem and the loose wire, when eventually found, was tightened with excellent results. The wind gust problem was mysterious until diagnosed, and was solved by overriding the airflow safety devices. In overriding the safety devices, the probability of a fan failure and the need to complete the testing were considered. (In Mexico, shunting switches were installed on the safety devices so that the override condition could be set easily according to wind conditions.)

c. Chronology and Test Conditions. The chronology and conditions of the testing are included implicitly in the fluids usage report (see Table 4-2) and usage plots (see Appendix E). This chronology is more comprehensive than the tables of test data discussed in Section VII.A.3., although the latter give the test conditions in chronological order for every row of 1978 data logged on tape. The test activities can be conveniently grouped by date for a discussion of the test highlights. Not all test dates are listed.

d. Highlights.

3/16 Initial test, smooth easy start, governor damaged at 1900 rpm.

3/20 Governor repair completed; resume shake-down testing of HSE power plant and test facility; check direction oil cooling fan and pumps; rewire fan motor; bleed air from hydraulic system; adjust governor.

3/21 Operate waste pump; work to stabilize P1; loss of in-plant voltage and fan operation; recover voltage.

3/22 Demonstration for Phillips' magazine photographers; cold oil requires slow start.

3/25 Continue to try to reach steady-state operation, all liquid feed; waste water recycle; reset temperature gauges to match RTDs; verify bubbles in liquid feed as cause of instability; work on controlling level in separator and waste tanks.

3/26 Demonstrate line start for pump without load shedding; repair tachometer generator; trouble with load bank.

3/28 - 4/5 Continue to try to stabilize all test systems, install 2-in. diameter feed pipe (too small); trouble with load bank; leaking pump seal; initiate 17-in. wide printer log.

4/6 Test with 6-in./8-in. diameter combination feed spool, try more load; begin to record data on tape.

4/10 Install manifold feed system: one 3-in.; two 2-in.; one 1-in. diameter; try to stabilize P1.

4/12 Install Lw, Ls, Ps gauges; adjust manifold relief valve.

4/18 Replace 3-in. pipe with 4-in.; attempt steady hands-off operation; short of feed liquid; oil showing in sight glass on waste tank.

4/19 Aim for continuous operation; basket screens clogged in supply lines to pumps; trouble with load bank; clean baskets and load bank relays; broke and repaired yoke pin in AS valve; made first test with steam from separator.

4/20 Work toward continuous operation; increase load.

4/21 Demonstration for DOE TV crew; load bank dropped 500 kW, plant continued to run; basket screens plugged.

4/23 Install solids trap in waste line to pumps, try to re-seal leaking shaft seals; conclude seal repair necessary.

Devise following test procedure:

(1) Close valve at Well 82-33; "two clicks."

(2) Monitor rise in Ls - when Ls reaches 110, start the plant.

(3) Monitor fall in Ls - when Ls = 70 to 80, start first pump.

(4) Adjust Mw to bring Ls to desired value.

This procedure permitted re-establishing the proper liquid level in the FTF separator in about 8 minutes. A useful process status board is shown in Figure 6-1. This status board was later replaced by a larger one made of plywood and attached to the face of the Data Van door.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

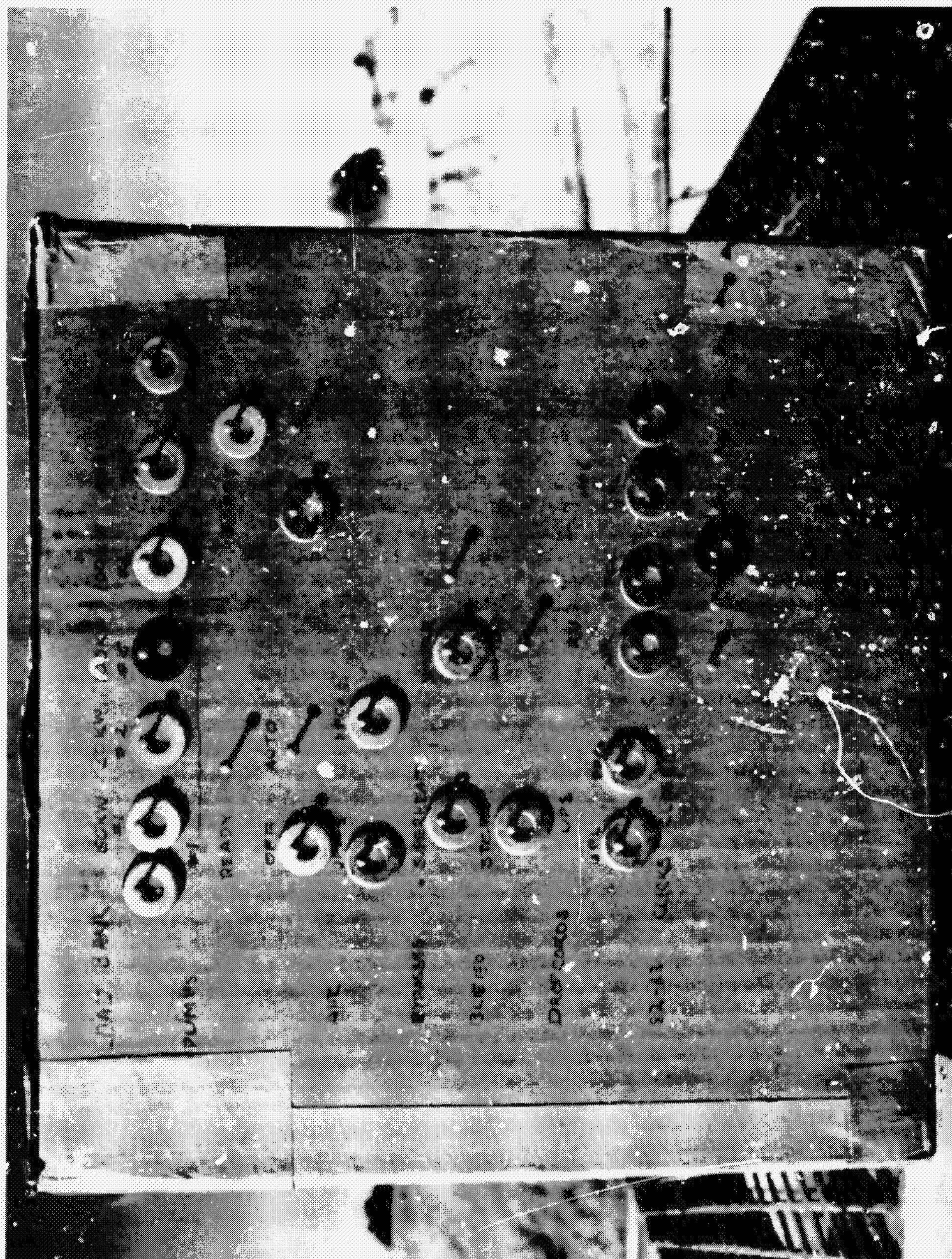

Figure 6-1. Process Status Board

4/25	Begin replacement of shaft seal assembly on low pressure end of male rotor.
5/3 & 5/4	Test with low enthalpy feed: simulate East Mesa.
5/5	Load bank wouldn't accept load.
5/6	Site shut down by snow.
5/7	Replace feed pipe from waste tanks to pumps (see Figure 5-8); install basket backwash; correct loose wire on load bank relay.
5/8	Demonstration for Phillips' magazine editor; increase Q1.
5/12	Demonstration for United States Department of the Navy visitors, test at various Q1; Ps low; install buffer air compressor for shaft seals.
5/13	Various P1 and Q1; try increased kW.
5/14	Increase Ps, try increased kW, various Q1 and P1.
5/16	Review data, try specific speed versus specific diameter correlations; conclude higher speed not desirable; consider remaining options within in limits of decreasing fluid supply: (1) install back-pressure plate, (2) investigate more low enthalpy feed conditions, (3) investigate high Q1, (4) propose change in level control of FTF separator; proposal accepted.
5/17 & 5/18	Design and fabricate adjustable back-pressure plate, revise level control for FTF separator.
5/19	Back-pressure tests; plate hole too small; modify back-pressure plate; override load bank safety switches (restored in 1980).
5/20	Complete back-pressure tests.
5/21	Test at high Q1: simulate Hawaii.

5/22 Begin endurance testing.

5/22 - 5/30 Maintained steady test conditions at maximum sustainable load.

5/30 Endurance testing terminated by seal assembly failure.

4. Staffing

The staffing varied according to the operations, and was at a maximum during the installation of the process piping. At that time the greatest number of contract personnel were at work on the site. During installation and test start-up the JPL staff varied from a normal minimum of one to four or five, and one or occasionally two during the testing. The HPC staff varied from one to three throughout most of the installation and testing. Most of the testing was conducted on a long day-shift basis, with a typical test crew of five or six, namely the principal investigator from JPL, the chief engineer and one mechanic from HPC, and two or three contractor operating personnel. This general approach was followed because the testing had become neither standardized nor assured. It proved best to keep the operation flexible, and to commit the fewest number of people. During the endurance or continuous testing the staffing was the same, except that the test crew was split to permit round-the-clock operation on a two 12-hour shift basis, although the principal investigator and the chief engineer worked the customary 12 to 16 hours to try to meet the test needs. Round-the-clock operation with no increase in staffing was feasible because the gathering of data for performance mapping had been completed within the limits of site conditions. The endurance testing was a steady state to the extent that fluid availability permitted.

C. REPAIRS, MODIFICATIONS AND OVERHAUL TEST PREPARATIONS

1. HSE Power Plant

The repairs and modifications of the power plant were performed by HPC in consultation with JPL. Included were repair of the HSE damage, re-design and replacement of the shaft seal assemblies, modification of the throttle trim, modification of the governor hydraulic system, and modification of the alternator. The power plant remained in place in Utah for this work, although the HSE was removed from its base.

The low-pressure end shaft of the male rotor was warped by the seal assembly failure and the bearing surface was slightly scarred by the removal of the damaged assembly. Repair of the shaft was done by Westinghouse Corp. (Westinghouse) in Salt Lake City under instructions from HPC. The damaged shaft was undercut on a new center, and then flame-sprayed and ground to restore the shaft and bearing surfaces. The rotor was then statically and dynamically balanced. The damaged journal bearing shoes were replaced, and the thrust bearing shoes were re-surfaced.

The inlet hardware was modified to provide inlet trim designed for different ranges of inlet pressure. The purpose was to permit a single throttle and governor system to provide stable operation for any resource pressure. The corresponding modification of the HSE housing end plate was done at Westinghouse to HPC specifications.

The hydraulic amplifier for the governor was replaced with one custom-designed to provide faster throttle response, with no dead band. The hydraulic oil supply to the governor system was increased by adding a new pump.

The repair of the shaft seals began with the removal of the damaged seal assembly in June 1978, soon after the termination of the testing, and ended with the final installation of the new assemblies on July 16, 1979. This repair was the pacing item in the overhaul. The repair procedure entailed the failure analysis, the outlining of a new design concept, reviews of the failure analysis and new design concept with seal manufacturers, the selection of a manufacturer, the completion of the design details, the manufacture of the seals and the assemblies, the testing of a seal assembly in the manufacturer's laboratory, the redesign and fabrication of one seal ring, the re-testing, delivery and installation of the assemblies, breakage of some seal segments during installation, manufacture of replacement segments, and final installation. The estimated completion date for the seal assemblies slipped from March 30 to April 27 to May 4 to May 29 to June 6 to July 6. This had a serious impact on the Project schedule and budget.

The seal delivery schedule would have been much more serious if it were not for two factors. First, overhaul of the power plant and other work at the test site were significantly delayed by heavy snows which made the site inaccessible during an extended period in February. It was impossible to deliver the HSE components to Westinghouse in Salt Lake City for repair and modification. Second, the FTF schedule slipped successively from December 1978, or January 1979, to June 4. The schedule slip was caused by the need for Phillips to continue monitoring the pressure recovery in the reservoir, and by delays resulting from the inaccessibility of the site. Start-up was actually attempted June 8, but the wellhead valve failed, causing a "blowout." The Well resumed operation August 22, but was shut-in again to replace the steam muffler that failed. It was restarted August 27, and fluid became available for testing the HSE on September 3. Thus, the FTF and this Project experienced parallel schedule slips which kept the two activities synchronized, at least through August.

During August, instrumentation wires from the expander which were disconnected during the overhaul were reconnected. Pre-operating adjustments of the speed control hydraulics and of the seal flush-water system were made. Further adjustments required operating the expander.

The alternator modification entailed the replacement of the standard cooling fan with a quieter model, and installing a cowling lined with sound-absorbent material to reduce the noise. The noise reduction was accomplished in part by greater clearance between the fan and the cowling around its periphery. The quiet fan moves 8% less air and draws 37% less power than the original fan. The expected noise attenuation was 12 to 15 db.

2. Process Piping

The process piping modifications for the 1979 testing were discussed in Section I.A.f. The most important modification was the installation of the steam condenser in one of the waste holding tanks, followed by a condensate-to-air heat exchanger, to supply condensate at 160°F or less to a flush-water holding tank at 4 gpm. The system produced about 900 gpd, but the quality was poor. Upon pressure reduction and loss of CO_2 and H_2S, the water turned from clear to black, presumably from an iron compound which precipitated but was slow to settle. Aeration turned the compound rust color and aided the settling slightly. A water treatment plant was designed and built by HPC for treating approximately 10,000 gpd of the condensate. The treatment consisted of aerating the water, flocculating it with bentonite, pumping it to a 20,000-gallon holding tank where the suspended solids settled, and then filtering it for delivery to the shaft seal flush-water system, as discussed earlier. Filtration was through 25 and 5-micron filters. The treatment was based partly on the HPC observation that the dark water cleared while trickling down the soil slope into the pit. The conductivities of samples of treated and untreated water are included in Appendix M.

A simple trough heat exchanger was installed on the water supply pipe from the FTF to reduce the temperature of the water to below boiling, during its flow through the orifice meter and water pipe to the power plant. The purpose was to eliminate the need to use recycled waste water to provide this temperature reduction in order to eliminate a possible interference with scale formation in the HSE. The heat exchanger used surplus untreated condensate made for the shaft seals to provide a heat sink of boiling water.

The manifolded set of small feed pipes to the power plant, constructed during the 1978 testing, was replaced with new interchangeable 4-inch and 6-inch diameter feed spools with mixer sections containing 6-element passive mixers. A similar mixer was installed to mix the recycled exhaust water upstream from the t_0 measurement. The process control valves were reinstalled, except that a lever-operated eccentric disc valve replaced the globe valve formerly used in the waste water line. A few additional minor changes, requested by Phillips, were made in the process piping following a general site review made by Phillips after the well "blowout."

A very significant modification was made to the FTF by Phillips. In order to control the water level in the separator, an eccentric disc valve was installed in the waste disposal pipeline as it passed the low point in the wash on the way to Well 82-33. The valve positioner and the level controller communicated by electrical signal. The valve was placed in the gulley to provide sufficient head on both sides to prevent flashing and water hammer. By contrast, JPL's temporary installation of the level control valve in the water line near the separator caused a water hammer a few times, and thus required careful attention to the water level in the disposal pipeline. The original level control in the FTF placed the control valve in the steam line to avoid scale problems in the control valve, but the eccentric disc valve design and the properties demonstrated in the waste water made the control modification feasible. The results were very satisfactory.

3. Data System

The computer operating program was upgraded for the 1979 testing, and two new 17-inch printers were added to the data system. This addition required the moving of the electronics rack to make room for a new table for the computer and printers. When the data system was reactivated to search for a transitory malfunction which was observed late in the 1978 testing, the problem had become severe. A bad power supply was discovered in the temperature signal-conditioning equipment which was swamping the system. The power supply was replaced, the 50-ohm signal-conditioning resistors were replaced with a higher quality type of resistor, and the p_0 and p_3 transducers were installed. Field corrections in the new computer program and a factory repair of the computer were made and the transducers were calibrated in preparation for the testing.

D. FIELD TEST OPERATIONS. 1979

Many test preparations were done concurrently with the plant overhaul and modifications discussed in Section VI.C. The first test attempt, made on September 3 when fluids from the FTF became available, showed that more preparations were necessary because problems were revealed in the HSE power plant and in the data system. Numerous additional diagnostic tests were necessary during the period of September 3 through October 12. These tests were not considered as part of the planned 1 month of tests.

1. Continuing Preparation

The fluids usage data, (see Table 4-3) show that during the continuing preparations, until October 12, the power plant operated 9 days in September for a total of 25.3 hours, and produced 4740 kWh of electrical energy. Diagnostic tests ranged in length from 15 seconds to approximately 6 hours.

a. HSE Power Plant. The September 3 test lasted about 15 seconds. It was terminated apparently by an unsatisfactory pressure differential across the seal assembly at the low pressure end of the female rotor. A series of investigations through September 4 revealed that a mud dauber insect had plugged an oil supply line to the low pressure end of the HSE while the oil line was disconnected during the overhaul. The blockage was removed, and the differential pressure fault sensors were rewired to correct another start-up problem.

Diagnostic runs on subsequent days revealed problems with the new hydraulic amplifier for the governor. HPC then undertook an amplifier development program using new spools modified at the site, stiffer centering springs, and modifications of internal oil routing. This development, plus revision in the feedback linkage to the governor, resulted in acceptable governor control by September 21.

b. Process Piping. Attempts to operate the disposal pumps on September 8 led to the discovery that the check valves in the pump discharge lines had been installed backward. Correction was simple.

c. Data System. Problems with the data system were numerous and delayed the testing until Ocotober 12 when the preparations were completed. Two factors may have extended the repair period. First, the well "blowout" gave the area a salt bath which caused some short circuits and may have caused some ground loops. The system malfunction was subtle and discontinuous, often reappearing only after the repair team left the site. Second, the JPL electronics engineer who designed, assembled and tested the data system, and who was thus most familiar with the hardware, left the Project. He returned to spacecraft projects during the hiatus in Project funding which followed the 1978 testing.

2. Testing

a. Chronology and Test Conditions. The chronology and conditions of the testing are included implicitly in the fluids usage report (see Table 4-3) and in tables of the test data presented in Section VII.A.3. The tables consist of all of the steady-state tests logged on tape in 1979. The test activities can be conveniently grouped by date for a discussion of the test highlights.

b. Highlights.

9/3 - 9/28 Diagnostic runs to complete test preparations.

10/12 Final diagnostic run; testing commenced with high pressure inlet trim and 4-inch feed spool; check entire system performance; calibration completed after data File No. 168; bleed lines closed;

correct p_2 equation at 16:19:06; varv inlet pressure, throttle position and load through attainable ranges to examine operating behavior of all test equipment; examine rotors for scale deposits -- none; decide to try to force scale deposits by injecting $CaCl_2$ solution into feed: [For this purpose calcium chloride was purchased during ensuing days from local cement-mix and tire companies; commercial grades from Allied Chemical (94 to 97%), Van Waters and Rogers, and Dow Chemical Co. "Dowflake" were used on the basis of availability.]

10/13 - 10/15 Obtain $CaCl_2$; obtain and install handling and injection equipment; mix in empty oil drums; use old oil gear pump.

10/16 Scale deposition trial; $CaCl_2$ @ 20 ppm, mixed basis; gooseneck feed; no visible deposits on rotors after shutdown; "cleaner than before;" check effect of rpm on efficiency; note increase at 58.2 Hertz versus 61.7 Hertz (see Table 7-2, File Nos. 188 and 189).

10/17 Inject $CaCl_2$ @ 1400 ppm; detect effect on throttle position early; see scale on rotors after shutdown.

10/18 Demonstration for Phillips and guests; no $CaCl_2$ injection; rotor inspection -- dark and white scale patches -- all blotchy.

10/20 Inject $CaCl_2$ into Pd port @ 1400 ppm to miss throttle gate; no efficiency improvement in 5 hours; stop to make gooseneck hook-up; rough stop; test done with Pump #2 because the start faltered upon adding Pump #1 two or three times; cause undetected; couldn't resume testing; rotors stuck; hailstorm.

10/21 Installed plastic-covered beaver board in exhaust flange and filled HSE with dilute HCl with 10-ppm sodium arsenite corrosion inhibitor donated by Phillips; soak; used 3 quarts of acid.

10/22 Added circulation pump, more acid and inhibitor; used 4 quarts of acid; coaxed with torque bar; rotors became free and turned easily.

10/23 Injected $CaCl_2$ alternately into gooseneck and Pd port @ 330 ppm, 5 hours; slight efficiency gain observed but very little scale observed through inspection ports.

10/24 Change to 6-inch feed spool; computer tape drive problem; ship for repair.

10/25 Couldn't start Pump #1; inject $CaCl_2$ into Pd port at higher load -- 600 kW, low Q1; monitor effects; slight improvement observed.

10/26 Trouble-shoot Pump #1; towed broken HPC truck to Milford; retrieved HPC van from Cedar City; buy $CaCl_2$.

10/27 Inject $CaCl_2$ into Pd port @ 370 ppm, 10% Q1, 1/2-MW load; no improvement during 4 hours; switch to gooseneck feed at 11:28:17 after port plugged; switched back about 11:42 @ 50 ppm for 1-1/2 hours; no improvement; resumed 370-ppm rate; no scale visible through inspection ports after test.

10/28 Increase Q1 to 25%, continue 1/2-MW load, $CaCl_2$ through Pd por ; little or no benefit observed; plant stopped automatically -- evidently from failure of pressure accumulator in shaft seal system.

10/29 Cold, snow, plant to operate on steam only; FTF separator out of control because of generator failure; home for Halloween during repairs.

11/03 "Steam only;" check performance versus th% at highest load attainable; then liquid only with $CaCl_2$ @ 50 ppm, low load; cold.

11/04 Snowing; inject $CaCl_2$ @ 1400 ppm, liquid-only feed and low load; shut down because of leak in oil supply line on power plant.

11/06 Scale deposition attempt at minimum stable load -- load bank and Pump #2; air in oil system -- slow start; scaling results disappointing; decision to abandon scale deposition attempts -- change to low pressure trim and measure performance; much precipitate downstream but not on rotors; flat tire.

11/11 Test with low pressure trim; test for performance match with other trim, low enthalpy feed, and high power; plant operation good; damaged Teflon support ring for orifice plate.

11/12 Drain pipe - remove damaged support ring and clips; flush-water filter cannister and oil filter element damaged by ice; damage to another Teflon orifice plate carrier.

11/13 Try for 3/4-MW and 1-MW at various Q1, then try for low Q1; ran out of fluid supply but reached 1-MW; no low Q1 tests.

11/14	Check flow meters at orifice overlap rates; considerable difficulty because of interference by the gradual shutting-in of the well; meters check okay.
11/15	Began disassembly.
11/16	Shipped assorted loan pool equipment to JPL on NASA plane.
11/28 - 11/29	Load equipment for shipment to Mexico.
11/30	Ship equipment.

3. Staffing

The testing in 1979 was done on the day shift only. Most of the tests were conducted by two men, one from JPL and one from HPC.

E. FIELD TEST OPERATIONS: 1980

A discussion of the field test operations in Mexico in 1980 is not within the scope of this report. The 1980 test results at 3000 rpm are included to provide an understanding of the significance of the 1978 and 1979 Utah test results, and to show how this Project has laid the foundation for testing the HSE power plant elsewhere. For a report on the field test operations in Mexico, refer to CFE.

SECTION VII

TEST RESULTS

A. TEST DATA

1. Pre-Delivery Testing: 1977

The pre-delivery data of the acceptance testing consisted of handwritten notes and a record printed on the computer thermal printer of all of the machine status parameters, including the fault annunciation. Notebooks were kept by the JPL principal investigator and by the HPC chief engineer during this and all other activities of this Project. For use in the acceptance testing, detailed procedures and checklists were written for static and dynamic testing of the HSE power plant, and for checking the interfacing with the data system. These procedures and checklists served both as a record of the acceptance testing, and as the basis for similar checklists used to check the installations and aid in the start-ups in Utah and Mexico. In addition, a power plant operator's log was prepared by HPC for this test and was maintained by HPC throughout this and all subsequent testing, with revisions in format as appropriate. An example of an acceptance and interface test procedure and checklist is presented in Appendix K. An example of the operator's log of the power plant is presented in Appendix N.

2. Utah Testing: 1978

The data for the 1978 testing in Utah was logged on the 2-1/2 inch wide computer thermal printer, on a 17-inch wide impact printer, and on computer tape according to operator instruction (see Figures 2-14, 2-15 and 2-16) as discussed earlier. As reported in Section IV.A.2.b., a condition of the Land Use Agreement was the reporting to Phillips of the daily fluid usage. The report was prepared by plotting requisite data from the operating log (see Figure 2-16) and integrating it graphically. A time interval of 7-1/2 minutes was used for the plots, and a planimeter was used for the integrations. The plots also serve as a visual record of the 1978 testing. The fluids usage data for the testing in 1978 is listed in Table 4-2, which was prepared for Phillips. Relevant information from a cover letter and some of the plots, including those for the endurance testing, are included in Appendix E.

The data on tape were all logged as final data sets, consisting of usually 10, 20 or 30 samples recorded by operator command under test conditions which appeared to be steady. Sixty-eight data sets were recorded starting with Set No. 2; Set No. 7 was inadvertantly recorded over, and thus erased, leaving 67 data sets. The set number was originally designated as run number. All 67 data sets, or runs, are reported here and are believed to be valid. In the data analysis, critical test parameters from the runs were tabulated and averaged to permit inspection, screening and subsequent processing of the data samples.

These tabulations and averages are presented by run number in Appendix O. For purposes of screening, the average absolute value of the deviations was calculated and shown, and all data points whose deviation exceeded three times the average deviation were identified. This identification was facilitated for Run Nos. 8 through 69 by listing the line and column numbers of those data points having three times the average deviation. The listings for Run Nos. 2 through 6 are not presented with the run data. If inspection showed that the deviation was significant in terms of magnitude and parameter, the entire data sample was discarded and the treatment repeated. From the resulting averaged data sets, the test results were calculated and displayed by the computer on the thermal printer. The 1978 results were eventually recalculated for presentation in Table 7-1. These results were initially stored in a standard matrix, but were eventually stored in a special Z matrix where they are identified in Table 7-1 by Row Nos. 1 through 67. Also, for computer programming convenience, 100 was added to the run numbers of the tables in Appendix O.

3. Utah Testing: 1979

The data for the 1979 testing in Utah was logged on the 2-1/2 inch wide computer thermal tape, on two 17-inch wide impact printers, and on computer tape according to operator instruction (see Figures 2-15, 2-17, 2-18 and 2-19), as discussed earlier. The fluids usage data from the operating log (Figure 2-19) were compiled and listed in Table 4-3 for delivery to Phillips. Relevant information from a cover letter is included in Appendix E. Plotting of the 1979 data was not necessary because the 1979 computer operating program did the necessary integration and summaries for Table 4-3.

The test data on tape were logged either automatically according to preselected times, or were recorded in sets commanded by the operator under test conditions which appeared to be steady. Some of the data which were logged automatically were logged at fortuitous times of steady operation during the testing, and others were not (see below). Therefore, the operating logs were carefully examined for steady operation, just preceding and following the recording on tape, as the basis for processing the data or not. The selected unprocessed data from the 1979 tests are presented in Table 7-2. It can be seen that the exhaust pressure tabulated as P2 was unstable for some of the data sets, especially at high load, making it appropriate to calculate the efficiency on the basis of exhaust temperature T2. Note also that Set No. 78 (five files, Nos. 15 through 19) is missing from the table, indicating that these data were not considered acceptable. The operating log showed that the test conditions were disturbed during the recording of this set. All other data sets were considered to be good. It should be pointed out, however, that subsequent to the preparation of Table 7-2, a correction was made in the calculation of gearbox losses in the power plant resulting in a small decrease in the calculated efficiency. It was not practical to replace Table 7-2 because of the computer time involved, but the corrected results appear in the subsequent data tabulations and were used in the data analysis.

Table 7-1. 1978 Utah Tape Data, Averaged Sets

1978 UTAH TAPE DATA AVERAGED SETS

Prepared 10/22/80

TDS= 5000 ppm; Inert gasses- wt% of stm (Proprietary)

Z(I) FILE

row	ave	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Ti	Qi	Pi	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	°/h	Trt%	KW	freq	eff%	eff2%	I2	P2	PF%
1	9	102	2	04/06	0:00:00	189	383	348.9	349.8	313.2	1.9	110	208	0	187	14	452	11	20	09	109	0.0	0	0	22	28	76	58.6	25.5	25.1	200.9	12	89.0
2	10	103	3	04/06	0:00:00	172	378	343.2	343.5	334.0	1.0	110	191	0	125	14	277	103	76	121	147	0.0	0	0	-1	38	135	61.0	30.4	29.8	200.9	12	96.9
3	11	104	4	04/06	0:00:00	187	377	350.6	352.0	340.6	1.2	120	180	0	114	13	246	102	24	130	154	0.0	0	0	2	41	103	60.8	32.6	32.4	200.9	12	98.0
4	12	105	5	04/06	0:00:00	197	378	352.3	354.7	330.1	2.8	104	190	0	122	14	443	154	28	163	191	0.0	0	0	-7	88	277	60.3	37.3	38.6	200.9	12	98.1
5	13	106	6	04/06	0:00:00	198	376	365.7	367.2	345.6	2.5	129	185	0	116	13	457	177	12	182	194	0.0	0	0	3	68	344	60.3	37.[illegible]	37.2	200.9	12	99.3
6	15	108	8	04/20	0:00:00	194	386	358.2	359.1	342.3	4.0	125	213	2	215	218	446	58	17	97	114	3.6	67	48	8	56	273	60.0	43.1	42.2	200.0	12	99.3
7	16	109	9	05/03	18:07:20	199	376	358.2	350.1	335.2	1.7	112	182	1	189	191	466	148	34	190	223	0.0	76	35	3	87	345	60.7	40.9	39.4	200.9	12	98.1
8	17	110	10	05/03	18:16:40	199	377	349.6	349.8	335.9	1.5	113	182	1	190	191	467	147	35	188	223	0.0	80	35	3	85	345	60.7	41.1	39.6	200.9	12	98.2
9	18	111	11	05/03	19:07:40	199	385	356.0	356.2	330.6	2.9	106	201	0	209	208	475	141	33	170	203	0.0	95	34	-1	95	343	60.6	41.9	40.5	200.9	12	98.1
10	19	112	12	05/03	19:35:20	200	388	355.8	355.9	312.7	2.7	108	213	0	219	219	477	138	35	166	202	0.0	89	33	1	92	343	60.6	42.1	40.8	200.9	12	98.1
11	20	113	13	05/03	19:47:41	200	388	356.1	356.1	355.2	-2.[illegible]	18	214	0	220	220	475	137	35	168	203	0.0	90	33	0	41	341	60.3	41.1	40.0	201.4	12	98.1
12	21	114	14	05/03	19:59:21	200	389	352.2	352.3	350.7	0.6	19	212	0	220	220	467	135	41	170	212	0.0	88	32	1	51	341	60.2	40.9	39.8	201.4	12	98.0
13	22	115	15	05/04	17:56:20	170	387	344.7	344.8	344.1	1.0	126	214	0	222	222	462	134	58	191	249	0.0	108	42	8	63	350	60.9	40.2	38.3	200.9	13	78.5
14	23	116	16	05/04	18:41:20	198	387	339.5	339.5	337.9	0.1	115	212	0	222	223	419	149	61	218	279	0.0	105	45	11	81	354	60.6	39.1	36.9	201.1	13	78.5
15	24	117	17	05/04	19:09:21	198	308	335.4	335.6	336.3	1.0	114	208	0	221	227	402	142	88	218	376	0.0	99	50	19	85	361	60.7	36.6	33.8	201.4	13	99.1
16	25	118	18	05/08	15:38:00	197	374	352.4	351.9	359.5	8.4	155	187	4	187	190	474	63	11	77	91	9.4	111	63	1	45	330	60.4	41.3	40.6	200.9	12	99.7
17	26	119	19	05/08	19:15:01	196	370	343.7	343.4	323.5	16.9	96	181	4	178	183	472	72	11	60	71	12.4	105	65	-0	97	333	60.2	46.2	45.3	200.9	12	99.9
18	27	120	20	05/09	19:21:00	196	370	344.0	343.4	323.1	16.9	95	182	4	178	164	472	29	11	60	71	12.4	103	65	7	98	333	60.2	46.3	45.2	200.6	12	99.7
row	ave	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Ti	Qi	Pi	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	°/h	Trt%	KW	freq	eff%	eff2%	I2	P2	PF%
19	28	121	21	05/08	19:27:00	196	370	343.8	343.5	323.1	17.0	95	180	4	178	183	471	48	11	60	71	17.4	103	65	1	98	333	60.1	46.2	45.4	200.0	12	99.9
20	29	122	22	05/12	11:15:30	151	332	322.8	322.5	325.1	10.5	76	106	5	103	110	471	75	4	72	76	9.1	116	86	-4	72	232	60.1	44.8	44.1	201.4	12	98.4
21	30	123	23	05/12	12:20:00	174	329	320.4	319.8	319.1	15.1	89	173	4	98	106	472	73	3	56	60	10.6	96	00	-8	77	231	60.0	45.0	44.4	201.4	12	98.2
22	31	124	24	05/12	12:49:00	180	328	317.3	317.4	317.6	19.9	88	105	4	97	107	475	71	4	43	47	11.7	120	75	-12	77	230	60.0	45.1	44.3	201.0	12	98.2
23	32	125	25	05/12	12:51:00	180	329	317.9	317.2	317.5	20.0	88	105	4	97	107	476	71	3	43	47	[illegible]	119	71	-12	70	231	60.1	45.1	44.3	201.0	12	98.2
24	33	126	26	05/12	13:21:30	183	327	313.8	313.8	314.9	24.6	85	105	4	95	106	475	71	3	35	38	12.5	122	68	14	88	229	60.0	45.2	44.4	200.9	12	98.4
25	34	127	27	05/12	13:26:00	184	327	314.3	313.7	314.9	24.7	84	106	4	95	107	473	71	3	34	38	12.[illegible]	124	67	14	80	229	60.0	45.3	44.5	200.9	12	98.6
26	35	128	28	05/12	14:05:00	188	339	334.4	334.2	332.9	5.2	107	116	4	116	121	476	72	3	103	106	5.7	127	68	6	63	231	60.2	43.3	42.6	201.4	12	98.5
27	36	129	29	05/12	14:08:00	188	339	334.9	334.4	333.2	5.2	109	117	4	116	121	476	72	3	103	106	5.8	120	68	6	62	231	60.3	43.2	42.4	201.4	12	98.3
28	37	130	30	05/13	10:40:20	169	340	330.0	330.1	326.4	9.9	100	118	5	115	121	510	72	6	89	94	10.1	114	81	2	88	312	60.0	47.2	46.2	200.9	12	97.2
29	38	131	31	05/13	10:44:20	170	340	331.3	331.3	327.1	9.7	101	110	5	115	122	512	71	5	89	94	9.6	114	81	2	86	308	60.1	46.9	45.9	200.9	12	99.2
30	39	132	32	05/13	11:07:30	177	333	328.3	328.1	320.7	15.0	93	115	4	109	117	497	76	4	67	71	12.0	102	80	-6	100	311	59.9	48.0	47.1	200.9	12	99.3
31	40	133	33	05/13	11:11:20	173	337	328.0	328.0	320.4	15.6	72	114	4	108	118	483	75	4	65	69	12.1	70	90	-7	100	309	58.9	48.2	47.3	200.9	12	99.4
32	41	134	34	05/14	10:36:00	146	359	364.4	364.4	348.4	9.8	135	173	4	175	170	489	72	2	104	106	9.4	91	95	5	71	427	60.4	46.3	45.2	200.4	12	100.6
33	42	135	35	05/14	10:41:20	147	369	364.1	364.1	348.4	7.7	135	173	4	175	177	491	70	2	103	105	9.3	70	96	6	70	423	60.5	46.3	45.2	200.4	12	100.1
34	43	136	36	05/14	11:23:20	152	357	348.8	348.8	344.5	19.8	128	155	4	148	157	491	70	3	59	62	15.0	87	93	-7	70	425	60.5	46.7	45.7	200.4	12	100.3
35	44	137	37	05/14	11:34:05	153	357	349.3	349.0	344.4	20.1	128	155	4	148	156	490	70	2	50	61	15.0	82	92	-7	71	424	60.4	46.9	45.9	200.4	12	100.1
36	45	138	38	05/14	13:36:00	179	360	355.7	355.3	350.7	15.2	179	159	4	152	160	495	66	2	86	88	15.4	115	04	3	80	524	60.2	47.7	46.6	200.4	12	100.7
37	46	139	39	05/14	13:40:20	179	359	355.5	355.4	351.1	15.3	140	159	4	153	161	492	64	2	85	87	15.5	116	85	3	80	520	60.1	47.2	46.3	200.4	12	100.5
38	47	140	40	05/15	11:10:00	183	373	370.2	370.2	359.0	9.9	155	182	4	181	186	595	133	2	139	141	13.8	78	69	6	87	635	60.2	45.3	44.0	200.4	12	100.1
39	48	141	41	05/15	11:20:21	184	373	369.9	370.2	359.7	9.8	157	182	4	181	187	587	133	2	137	140	13.6	80	69	-6	85	632	60.3	45.5	44.2	200.4	12	100.1
40	49	142	42	05/15	11:56:40	190	362	354.1	354.5	348.6	19.8	136	168	4	154	168	524	103	4	77	81	19.3	111	63	13	97	589	59.9	47.3	46.0	199.9	12	100.0
41	50	143	43	05/15	11:59:00	191	362	353.5	354.1	348.7	19.7	136	168	4	154	169	523	103	4	77	81	19.4	112	62	13	97	589	59.8	47.0	45.8	199.9	12	100.1

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Table 7-1. (Cont'd)

1[illegible] UTAH TAPE DATA AVERAGED SETS

TDS- 5000 ppm;Inert gasses= wt% of stm (Proprietary)

Z11 FILE

rev	ave	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Tl	Ql	Pl	Pf	Tsep	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	%/h	Trt%	KW	freq	eff%	eff2%	T2	P2	PF%
42	51	44	44	05/15	13:23:20	192	374	370.9	370.9	366.3	5.7	170	193	4	190	199	540	97	4	216	270	12.6	122	67	30	97	754	60.5	43.4	41.0	201.4	13	100.4
43	52	145	45	05/19	16:07:30	188	378	361.3	367.5	352.4	16.4	141	198	4	198	217	500	62	5	70	75	13.1	98	99	-0	62	173	59.7	34.3	32.9	249.3	31	97.5
44	53	146	46	05/19	16:13:30	189	376	360.2	360.3	339.9	16.8	118	193	4	193	214	495	60	5	77	82	14.1	98	99	3	96	177	59.0	37.9	36.0	252.7	33	97.3
45	54	147	47	05/20	13:35:01	185	392	384.2	383.5	352.7	14.9	143	237	4	238	240	505	60	3	72	75	9.9	98	52	-0	52	33[illegible]	[illegible]	43.0	42.0	211.6	15	99.9
46	55	148	48	05/20	13:37:31	185	392	384.0	383.6	352.4	15.0	143	237	4	238	241	506	59	3	72	75	9.9	98	52	0	52	335	60.4	43.0	42.0	211.7	15	99.6
47	56	149	49	05/20	14:06:00	189	380	370.3	369.3	352.3	19.2	143	205	4	203	221	498	60	4	73	77	16.6	78	51	1	79	337	60.0	46.0	44.2	242.9	28	99.8
48	57	150	50	05/20	14:17:30	190	378	367.5	368.6	358.6	20.1	154	203	4	200	218	500	60	4	67	71	16.9	98	51	1	65	338	60.7	44.4	42.9	241.5	27	99.9
49	58	151	51	05/20	14:18:31	190	379	367.5	368.5	357.8	20.2	153	203	4	200	218	501	60	4	67	71	17.0	98	5[illegible]	-1	67	338	60.3	44.4	43.0	241.9	27	100.0
50	59	152	52	05/20	14:40:03	191	383	377.5	377.2	361.0	15.1	159	212	4	211	230	461	80	3	94	97	15.2	98	51	1	72	345	60.2	45.2	43.4	247.1	30	99.8
51	60	153	53	05/20	14:44:00	191	383	377.3	377.3	361.1	15.1	160	211	4	210	229	461	80	3	93	95	15.0	98	51	-0	70	342	60.2	45.1	43.4	246.8	30	100.0
52	61	154	54	05/20	15:05:15	193	391	383.0	387.2	350.8	10.2	155	232	3	234	251	408	110	2	131	131	10.3	97	50	1	80	348	60.2	46.7	45.0	248.2	30	99.8
53	62	155	55	05/20	15:07:45	193	392	388.3	387.7	361.2	10.1	159	234	3	236	252	408	109	2	129	131	10.3	97	50	0	77	349	60.1	46.7	44.8	247.6	30	99.9
54	63	156	56	05/20	15:52:30	196	401	394.3	393.9	369.2	4.9	177	260	3	264	277	369	119	6	160	166	3.7	97	51	5	62	344	60.3	45.2	43.7	241.9	27	99.7
55	64	157	57	05/20	15:55:55	196	401	394.2	394.0	365.9	5.3	170	260	3	263	278	368	118	6	163	169	3.7	97	51	7	67	348	60.3	45.5	44.0	242.6	27	99.9
56	65	158	58	05/21	21:08:29	169	396	384.5	392.6	342.6	23.0	123	231	4	236	235	464	78	2	38	40	8.8	98	73	-16	50	288	59.8	47.5	46.6	200.4	12	99.0
57	66	159	59	05/21	21:26:54	172	397	393.9	391.0	349.9	62.7	136	226	5	226	228	477	77	0	10	10	15.2	98	71	-24	38	292	60.7	39.9	39.2	199.9	12	99.2
58	67	160	60	05/21	21:27:14	173	387	388.1	385.4	344.1	77.0	129	210	4	207	218	477	76	-0	5	5	15.5	115	70	25	40	293	60.5	42.0	41.2	199.9	12	99.1
59	68	161	61	05/21	21:33:00	174	378	369.5	382.0	343.3	42.4	127	202	4	201	203	472	76	1	22	23	14.7	117	68	-21	42	291	60.2	38.7	38.0	199.9	12	99.0
60	69	162	62	05/21	21:36:19	175	374	369.3	382.6	346.8	44.5	131	204	4	202	206	474	76	0	20	20	14.5	117	67	-21	41	296	60.3	40.0	39.1	199.9	12	99.1
61	70	163	63	05/21	21:40:42	176	370	363.6	374.6	348.9	41.9	136	205	4	203	206	474	76	1	21	21	14.2	120	66	-21	38	289	60.3	39.4	38.6	199.9	12	99.2
62	71	164	64	05/21	21:53:18	176	371	369.9	354.2	333.6	62.4	110	196	4	194	198	515	50	0	10	10	16.1	98	63	-14	51	284	59.6	41.0	40.2	199.9	12	98.8
63	72	165	65	05/21	21:55:30	176	368	367.6	353.1	332.4	62.5	100	194	4	193	196	514	50	0	10	10	16.1	99	62	-14	52	281	59.6	41.3	40.4	199.9	12	99.0
rev	ave	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Tl	Ql	Pl	Pf	Tsep	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	%/h	Trt%	KW	freq	eff%	eff2%	T2	P2	PF%
64	73	166	66	05/24	11:07:00	196	399	391.1	390.7	340.6	5.1	132	252	0	259	259	441	96	5	117	122	0.0	97	60	-1	53	294	60.2	41.5	40.9	200.9	12	98.8
65	74	167	67	05/24	19:17:00	195	400	391.8	391.4	355.0	4.3	146	257	0	263	262	443	96	5	117	121	0.0	97	49	-1	44	291	60.4	40.8	40.1	200.7	12	99.1
66	75	168	68	05/26	17:25:00	197	396	387.6	387.3	346.9	4.8	130	245	0	250	248	433	86	5	117	122	0.0	92	77	3	53	289	60.0	42.6	41.9	200.9	12	99.0
67	76	169	69	[illegible]	19:10:27	197	396	385.4	387.6	344.0	5.2	125	243	0	251	248	431	86	7	108	115	0.0	93	79	0	56	287	59.9	45.0	44.3	200.9	12	99.1

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Table 7-2. 1979 Utah Tape Data, Unprocessed

1979 UTAH TAPE DATA UNPROCESSED
[illegible]
TDS= 5000 ppm,Inert gas [illegible] wt% of stm (Proprietary)

File	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Ti	Gi	Pi	Pf	Tsup	Pv	Ps	Pw	Nw	Nr	Ns	NF	Nv	Ls	Lw	'/h	Trt%	FW	freq	eff%	eff2%	T2	F2	Pd	FF%
169	0	0	10/12	16:59:17	183	416	376.7	376.3	375.3	7.6	202	297	0	304	308	358	100	17	1	110	0.0	84	74	10	11	135	59.6	34.9	34.8	201.5	12.0	176	101.7
170	0	0	10/12	17:23:44	187	415	377.7	377.5	377.4	-13.0	221	294	0	303	307	358	100	19	93	112	0.0	84	70	10	7	105	59.8	33.0	33.4	201.5	11.6	177	102.8
171	0	0	[illegible]	17:34:36	189	415	377.5	376.3	330.2	4.6	115	298	0	304	308	359	100	19	89	107	0.0	83	67	11	85	101	59.7	36.4	36.4	201.5	11.8	74	102.7
172	0	0	[illegible]	17:40:57	189	415	376.7	376.5	335.7	4.9	111	297	0	304	308	357	101	19	88	107	0.0	84	67	11	100	103	59.9	36.4	36.8	201.5	11.6	93	102.8
173	0	0	10/12	17:57:06	191	416	385.6	385.5	370.2	5.7	195	295	0	304	308	360	102	19	114	133	0.0	84	65	4	10	286	60.1	36.9	37.2	201.5	11.7	175	105.1
174	0	0	10/12	18:06:54	191	416	387.1	386.9	386.7	15.1	252	295	0	304	308	367	103	19	121	140	0.0	84	64	-3	0	204	60.6	35.4	35.3	201.5	12.0	291	105.3
175	0	0	10/12	19:15:49	192	416	386.3	385.7	351.5	4.2	157	294	0	304	308	356	100	18	113	131	0.0	84	64	-4	100	205	59.6	39.9	38.9	201.5	11.8	113	104.8
176	0	0	10/12	18:47:54	193	417	392.0	391.8	370.3	[illegible]	193	293	0	305	310	279	112	18	138	156	0.0	94	52	-1	50	376	[illegible]	38.3	38.1	201.6	12.0	172	106.4
177	0	0	10/12	18:58:11	193	417	393.2	393.0	392.7	9.2	252	292	0	304	309	277	112	18	144	162	0.0	84	52	0	12	370	[illegible]	36.5	36.4	201.8	12.0	213	105.1
178	0	0	10/12	19:00:08	194	417	393.5	393.1	392.9	7.3	253	292	0	305	310	278	113	18	145	162	0.0	84	62	1	12	378	60.3	36.4	36.3	201.8	12.0	214	105.8
179	0	0	10/12	19:12:15	174	416	392.7	392.1	366.6	3.2	166	292	0	304	309	250	112	17	137	157	0.0	84	61	1	80	382	59.8	39.2	38.9	201.5	12.0	137	105.7
180	0	0	10/12	20:17:17	171	407	406.3	405.9	351.3	3.0	225	275	0	303	310	330	130	0	132	132	0.0	94	53	9	33	355	60.2	37.5	37.4	201.6	11.9	200	107.1
182	1	0	10/16	11:30:44	145	410	404.4	403.4	359.6	4.3	170	277	0	303	310	511	67	2	83	85	0.0	84	53	0	20	173	59.8	33.3	33.4	202.0	12.0	143	101.7
183	1	0	10/16	12:30:46	178	410	405.8	404.9	[illegible]	5.0	163	297	0	301	308	504	66	2	82	84	0.0	84	54	0	12	174	59.7	33.5	33.7	202.0	11.9	146	101.6
184	1	0	10/16	13:30:47	156	411	407.3	407.0	365.9	5.2	164	297	0	301	308	501	66	1	81	83	0.0	84	53	1	11	173	59.7	33.0	33.4	201.7	11.7	[illegible]	[illegible]
185	1	0	10/16	14:30:49	171	411	408.0	407.2	366.0	5.2	164	297	0	302	309	500	66	1	91	92	0.0	83	53	-1	12	173	59.7	33.4	33.6	202.0	11.0	[illegible]	101.7
186	1	0	10/16	15:30:50	193	411	407.6	407.1	361.9	5.4	159	296	0	299	306	498	67	1	80	82	0.0	94	52	-1	33	172	59.6	33.3	33.0	202.0	11.6	134	101.1
187	1	0	10/16	16:30:51	173	411	407.7	406.9	363.2	5.5	157	297	0	302	309	502	67	1	83	84	0.0	43	51	-0	35	173	59.8	32.7	[illegible]	202.0	11.7	133	101.1
188	1	0	10/16	17:21:39	193	411	407.9	406.9	367.0	5.1	165	277	0	302	308	530	71	1	82	83	0.0	84	50	-2	32	175	61.7	32.8	33.4	202.0	11.6	135	101.7
189	1	0	10/16	17:30:54	193	411	408.7	407.5	364.4	5.4	161	297	0	302	308	401	63	1	82	83	0.0	[illegible]	[illegible]	1	34	181	58.2	33.8	34.4	202.0	11.6	136	100.9
192	2	0	10/17	17:45:15	149	411	408.5	407.7	366.6	5.2	164	297	1	303	307	512	64	1	79	80	0.0	84	56	-0	56	175	59.6	34.2	34.6	201.5	11.6	23	101.8
193	2	0	10/17	18:45:17	174	412	409.5	408.9	374.6	4.4	162	278	1	304	[illegible]	510	64	1	76	77	0.0	14	55	-1	50	176	59.7	34.9	35.3	201.5	11.6	136	101.1
196	2	0	10/18	12:11:45	118	412	408.7	408.2	362.4	5.8	156	298	0	304	309	523	54	1		90	0.0	84	72	1	35	173	[illegible]	33.5	34.2	201.5	[illegible]	130	102.5
197	2	0	10/18	13:11:47	166	412	409.7	409.0	362.2	5.7	[illegible]	298	0	[illegible]	308	519	64	1	80	81	0.0	84	72	0	36	176	60.2	33.8	34.0	201.5	11.7	130	101.0
198	2	0	10/18	14:11:49	[illegible]	412	410.2	409.4	348.4	5.2	159	299	0	304	309	515	64	1	79	79	0.0	84	72	-1	29	175	60.1	33.7	34.0	201.4	11.6	141	130.9
199	2	0	10/18	15:11:51	152	412	410.2	409.5	370.0	4.9	174	278	0	304	309	515	63	1	78	78	0.0	84	72	-1	27	174	60.1	34.0	34.3	201.5	11.7	140	101.3
File	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Ti	Gi	Pi	Pf	Tsup	Pv	Ps	Pw	Nw	Nr	Ns	NF	Nv	Ls	Lw	'/h	Trt%	FW	freq	eff%	eff2%	T2	F2	Pd	FF%
200	2	0	10/18	15:11:53	135	412	407.7	407.2	371.7	4.7	176	299	0	304	310	513	62	1	80	81	0.0	33	73	0	26	174	60.1	32.6	33.1	201.1	11.4	150	101.5
201	2	0	10/18	17:11:54	174	412	410.3	409.6	359.6	5.0	172	[illegible]	[illegible]	305	315	518	62	1	80	[illegible]	0.0	83	73	0	28	176	60.1	33.3	33.6	201.1	11.6	147	105.4
203	3	0	10/20	11:07:48	111	414	411.6	410.7	[illegible]	5.6	145	302	0	300	316	515	53	1	77	79	0.0	74	89	-0	31	176	60.6	33.7	34.0	201.5	11.6	14	[illegible]
204	3	0	10/20	12:39:49	125	413	411.2	411.0	371.3	5.2	173	303	0	310	318	526	51	1	78	79	0.0	74	89	0	27	174	60.1	33.2	33.5	201.6	11.7	14	105.3
205	3	0	10/20	13:57:51	145	414	412.0	411.3	362.8	6.4	153	302	0	310	318	513	64	0	78	78	[illegible]	79	90	-1	37	177	59.9	34.2	34.9	201.9	11.5	13	104.1
206	3	0	10/20	14:57:52	159	414	412.7	412.2	359.8	6.4	154	301	0	309	317	509	65	0	78	79	0.0	84	89	-1	39	173	59.9	33.4	33.9	201.7	11.6	13	102.8
211	4	0	10/23	12:29:41	117	409	408.6	408.3	371.0	2.1	224	292	0	278	305	345	120	0	144	144	0.0	84	76	-2	38	389	59.7	36.6	36.7	202.0	11.9	14	105.4
212	4	0	10/23	13:29:40	156	407	438.6	409.2	393.3	1.8	231	271	0	298	396	341	121	0	141	141	0.0	34	71	-3	40	395	59.9	39.0	37.9	202.0	12.0	16	[illegible]
213	4	0	10/23	14:29:41	244	409	408.5	450.2	376.0	1.4	239	274	0	279	306	340	121	0	138	138	0.0	84	67	-4	41	394	59.9	39.7	[illegible]	202.0	12.0	15	103.5
214	4	0	10/23	15:29:42	[illegible]	437	408.9	408.3	374.3	1.7	234	273	0	279	306	379	121	0	138	138	0.0	94	62	4	48	394	59.9	38	38.7	202.0	12.0	16	103.4
215	4	0	10/23	16:29:43	[illegible]	407	[illegible]	409.6	375.1	1.6	[illegible]	274	0	301	307	340	120	0	137	137	0.0	43	57	4	50	395	[illegible]	38.7	38.7	202.0	12.0	16	103.5
216	4	0	10/23	17:29:16	[illegible]	439	409.2	409.6	374.5	1.7	234	273	1	300	307	339	120	0	137	137	0.0	84	52	4	51	772	59.8	38.4	38.5	202.2	12.0	16	102.7
218	5	0	10/25	17:24:52	317	410	407.9	409.2	379.7	1.0	231	272	0	301	398	273	115	0	155	155	0.0	34	92	4	31	444	60.1	38.5	37.5	200.9	12.4	15	102.2
219	5	0	10/25	18:11:31	[illegible]	413	411.6	409.8	401.7	0.8	257	276	0	303	399	277	[illegible]	6	199	205	0.0	84	89	9	54	613	57.7	33.3	38.1	201.1	11.9	15	102.4
220	5	0	10/25	17:11:32	371	412	411.6	459.7	402.2	3.8	257	296	0	302	310	[illegible]	127	7	179	286	0.0	34	85	10	52	610	57.9	38.5	37.6	201.1	12.1	16	102.5
221	5	0	10/25	[illegible]	[illegible]	413	411.9	410.1	402.2	0.8	258	275	0	302	310	[illegible]	129	8	175	292	0.0	73	84	9	52	699	59.8	40.9	38.2	201.1	11.0	15	102.4
224	6	0	10/27	[illegible]	[illegible]	407	406.4	406.1	450.7	10.1	[illegible]	[illegible]	1	[illegible]	302	441	100	0	192	102	[illegible]	[illegible]	75	6	45	541	60.0	37.1	38.4	201.0	12.3	14	101.0
225	6	0	10/27	[illegible]	[illegible]	407	[illegible]	[illegible]	470.1	10.1	273	276	1	274	301	440	102	0	101	101	10.9	[illegible]	81	7	51	541	59.9	37.4	38.7	200.9	12.2	14	103.2
226	6	0	10/27	11:02:15	[illegible]	[illegible]	406.3	405.6	[illegible]	10.0	[illegible]	295	3	274	300	440	101	0	[illegible]	102	10.9	34	77	7	52	542	60.0	39.3	38.6	[illegible]	12.3	13	103.7
227	6	0	10/27	14:13:17	[illegible]	406	406.0	[illegible]	379.2	10.1	[illegible]	285	1	[illegible]	299	419	78	0	100	100	[illegible]	34	74	6	72	510	60.0	37.7	39.0	200.6	12.2	14	101.2
228	6	0	10/27	15:07:09	190	407	406.4	406.0	379.4	10.2	[illegible]	206	1	274	300	439	92	0	101	101	19.8	84	70	4	51	[illegible]	60.1	35.6	[illegible]	200.6	12.2	16	101.3
229	6	0	10/27	16:07:40	[illegible]	407	406.9	404.1	400.3	10.1	[illegible]	207	3	276	301	419	92	0	101	101	10.7	84	66	4	50	543	60.0	37.5	38.0	200.5	12.2	14	101.4
230	6	0	10/27	17:17:41	195	406	406.0	[illegible]	450.3	9.7	[illegible]	207	3	[illegible]	301	440	92	0	101	101	10.7	84	62	4	10	[illegible]	[illegible]	[illegible]	38.8	200.6	12.1	16	101.3
231	6	0	10/27	18:07:41	191	411	410.5	409.0	410.9	10.7	276	278	1	298	404	440	92	0	99	77	11.0	83	59	5	0	540	60.0	39.0	38.5	200.7	[illegible]	14	103.4
234	7	0	10/28	[illegible]	[illegible]	404	402.7	402.0	481.0	[illegible]	257	278	1	297	296	540	49	0	52	52	17.6	64	52	3	18	517	60.0	39.1	37.6	200.0	11.9	14	102.5
235	7	0	10/28	12:56:20	157	403	401.2	399.7	400.2	25.1	255	295	3	[illegible]	293	[illegible]	47	0	52	51	17.9	94	51	2	39	541	59.9	38.1	35.6	159.0	11.9	16	[illegible]
236	7	0	10/28	[illegible]	171	404	402.4	401.0	[illegible]	25.4	268	208	3	287	296	[illegible]	47	0	51	[illegible]	17.7	34	50	2	10	539	60.0	38.2	37.7	199.6	11.9	13	103.2
237	7	0	10/28	14:54:25	[illegible]	401	399.9	379.6	491.5	25.2	[illegible]	[illegible]	1	[illegible]	297	542	47	0	51	51	17.7	83	[illegible]	2	17	540	60.2	38.6	38.0	179.7	12.0	15	103.2
246	9	0	11/03	[illegible]	[illegible]	[illegible]	343.5	[illegible]	[illegible]	99.0	219	[illegible]	3	275	250	217	0	0	0	0	26.4	54	62	0	36	515	60.3	[illegible]	35.5	178.8	11.7	13	101.9

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Table 7-2. (Cont'd)

1979 UTAH TAPE DATA UNPROCESSED
TDS= 5000 ppm, Inert gasses= [illegible] of stm (Proprietary)

File	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Ti	Qt	Pi	Pr	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mn	Ls	La	%h	Trt%	KW	freq	eff%	eff2%	T2	P2	Pd	Pf%
247	9	0	11/03	13:26:00	135	357	357.3	349.9	396.4	96.8	242	204	3	275	298	278	0	-0	0	0	26.0	84	63	0	30	533	60.1	34.4	33.9	198.0	11.8	14	104.2
248	9	0	11/03	13:37:41	136	357	[illegible]	[illegible]4.4	352.1	99.7	141	286	3	277	292	279	0	0	0	0	26.0	84	63	0	92	532	60.2	42.5	41.0	199.0	11.0	14	105.0
249	9	0	11/03	14:37:42	97	46	[illegible]	[illegible]0.1	370.0	3.0	172	294	0	301	305	533	63	0	87	87	0.0	83	67	2	27	100	60.3	34.1	34.1	200.7	11.7	15	97.9
250	9	0	11/03	15:40:22	97	390	389.4	389.4	361.6	3.5	155	292	0	300	305	456	87	0	94	94	0.0	84	66	-4	35	104	59.9	35.8	35.5	201.0	11.9	13	99.9
251	9	0	11/03	16:40:23	131	403	402.0	401.4	366.5	4.4	165	295	0	303	300	456	87	0	87	87	0.0	84	60	-6	31	104	60.1	34.2	34.5	200.8	11.5	13	99.6
253	10	0	11/04	11:47:36	95	405	405.0	404.0	366.6	4.0	164	293	0	300	306	467	86	0	84	84	0.0	84	57	-7	31	101	60.1	34.2	34.5	201.0	11.5	13	99.3
255	11	0	11/06	11:59:46	94	411	410.8	409.6	346.1	7.1	137	294	0	297	301	542	51	0	56	56	0.0	84	53	-2	25	69	60.3	25.6	26.0	203.0	11.9	9	83.0
256	11	0	11/06	12:59:47	132	411	411.0	409.7	346.7	7.0	139	293	0	296	300	530	50	0	56	56	0.0	84	51	-2	62	60	60.0	25.2	25.6	203.0	11.9	9	82.3
257	11	0	11/06	13:59:40	158	411	410.5	409.6	354.0	5.8	157	293	0	295	297	535	51	0	54	54	0.0	84	48	-3	48	70	60.3	26.1	26.5	202.9	11.0	10	82.0
258	11	0	11/06	14:59:50	170	406	405.6	404.6	355.7	4.7	166	293	[illegible]	295	299	537	51	0	55	55	0.0	84	45	-3	45	69	[illegible]	26.4	27.0	203.0	11.8	9	82.4
260	11	0	11/06	17:01:18	180	410	409.4	408.5	351.3	6.2	149	295	0	297	301	529	51	0	51	51	0.0	84	34	-4	62	60	60.0	27.9	28.4	203.0	11.0	11	80.9
261	11	0	11/06	18:01:48	179	409	408.1	407.3	340.9	7.3	129	296	0	299	305	535	51	0	51	53	0.0	85	29	-3	60	77	60.3	20.3	20.8	203.3	11.9	9	83.7
263	11	0	11/06	19:14:06	179	409	408.4	407.5	344.[illegible]	7.0	134	295	0	298	304	553	38	0	52	52	0.0	85	31	1	65	63	60.3	26.9	27.4	203.1	11.0	9	80.7
267	12	73	11/11	13:23:17	302	408	407.6	407.0	372.1	3.5	193	285	0	296	300	294	143	0	174	174	0.0	85	55	-2	14	510	60.1	1	41.0	204.0	10.1	193	102.9
268	12	73	11/11	13:23:17	305	408	407.6	407.1	370.1	3.9	186	283	0	296	299	291	142	0	163	163	0.0	84	55	-4	36	517	60.0	4[illegible].9	44.1	204.0	14.1	164	102.6
269	12	73	11/11	13:23:17	310	407	407.2	407.1	369.2	4.0	185	285	0	276	300	293	142	0	174	175	0.0	85	55	-1	37	517	60.1	39.9	41.1	204.0	11.0	105	102.6
270	12	73	11/11	13:23:17	313	408	407.5	407.1	370.6	3.0	189	285	0	296	300	292	140	0	170	170	0.0	85	55	-1	36	518	60.0	45.5	42.1	204.0	14.5	165	103.2
271	12	73	11/11	13:23:17	316	408	407.5	406.9	371.6	3.7	190	283	0	295	299	291	140	0	170	171	0.0	85	55	-1	36	517	60.1	41.7	42.0	204.0	12.3	157	103.2
272	12	0	11/11	13:2[illegible]:38	321	407	407.1	406.9	36[illegible].9	4.1	182	282	0	294	299	291	136	0	171	171	0.0	85	55	0	98	518	60.0	41.3	39.6	197.8	12.0	169	103.0
273	12	74	11/11	13:39:32	346	407	406.8	406.5	332.5	8.2	115	28[illegible]	0	294	298	291	133	0	171	171	0.0	84	55	1	97	514	60.0	39.8	45.5	204.0	9.2	107	103.3
274	12	74	11/11	13:39:32	346	407	407.0	405.4	331.0	8.4	112	282	0	294	300	291	133	0	171	171	0.0	85	55	2	100	506	59.7	50.8	45.3	204.0	15.2	89	103.2
275	12	74	11/11	13:39:32	347	407	407.1	406.5	331.0	8.4	112	283	0	293	298	290	132	-0	173	173	0.0	85	55	3	100	510	59.9	52.0	45.1	204.0	15.9	98	103.0
276	12	74	11/11	13:39:32	347	407	406.9	406.4	331.5	8.3	113	282	0	275	299	289	132	1	169	170	0.0	83	55	0	100	510	60.0	41.0	45.9	204.0	10.1	104	103.1
277	12	74	11/11	13:39:32	348	407	407.1	406.5	332.0	8.2	115	283	0	295	299	291	133	0	164	164	0.0	84	55	-0	96	511	60.0	51.5	47.4	204.0	14.5	96	103.1
278	12	0	11/11	13:41:26	349	407	407.0	406.7	331.4	8.4	112	283	0	295	299	291	132	0	167	169	0.0	85	55	1	99	506	59.8	46.1	45.7	203.0	12.7	97	102.9
279	12	75	11/11	14:05:54	349	393	393.2	394.4	368.2	15.0	187	285	4	287	294	286	131	-0	80	80	11.9	85	50	-23	29	505	60.0	41.2	44.1	203.0	10.3	107	103.5
280	12	75	11/11	14:05:54	349	393	393.1	394.1	367.7	15.0	186	285	4	286	292	284	131	-1	81	80	11.9	84	50	-23	29	505	60.1	42.5	44.2	203.0	11.1	173	102.8
281	12	75	11/11	14:05:54	348	393	392.8	394.1	368.2	15.1	185	285	4	287	292	284	130	0	79	80	11.8	85	50	-23	30	504	60.2	43.5	44.0	203.0	11.7	140	103.0
File	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Ti	Qt	Pi	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mn	Ls	Lw	%/h	Trt%	KW	freq	eff%	eff2%	T2	P2	Pd	Pf%
282	12	75	11/11	14:05:54	348	393	393.0	393.9	368.2	14.7	186	284	4	287	271	284	131	-0	81	81	11.9	84	49	-23	29	505	60.2	46.3	43.9	203.0	13.9	171	103.1
283	12	75	11/11	14:05:54	348	393	393.0	393.9	368.2	14.8	186	285	4	286	292	283	131	-1	81	80	11.8	84	49	-23	29	505	60.0	43.5	44.2	202.5	11.7	167	103.4
4	12	76	11/11	14:23:44	290	394	394.3	393.2	325.1	16.1	105	285	4	289	293	479	76	-0	74	94	9.6	85	48	0	100	486	60.0	51.2	51.0	203.0	12.3	92	103.1
5	12	76	11/11	14:23:44	293	394	394.3	393.2	325.1	16.2	104	285	4	289	294	480	77	0	93	93	9.6	83	48	0	100	482	59.9	51.1	51.0	203.0	12.3	89	102.9
6	12	76	11/11	14:23:44	289	395	394.5	393.2	325.1	16.2	104	286	4	289	294	482	77	0	94	94	9.7	85	48	-0	100	486	60.0	50.7	50.9	203.0	12.1	93	102.8
7	12	76	11/11	14:23:44	288	394	394.6	393.2	325.6	16.2	105	286	4	299	295	480	76	0	93	93	9.7	86	48	0	100	484	60.0	50.8	51.0	203.0	12.1	93	103.2
8	12	76	11/11	14:23:44	287	394	394.3	393.2	325.1	16.2	105	285	4	289	295	482	76	0	93	93	9.7	84	48	-0	100	486	60.2	51.2	51.2	203.0	12.2	92	102.7
9	12	0	11/11	14:41:20	240	388	384.0	387.5	364.9	23.6	179	275	4	282	289	484	78	0	48	49	13.7	85	47	-13	29	478	60.5	49.3	49.4	202.8	12.1	151	103.4
10	12	77	11/11	14:51:59	222	383	382.7	385.5	368.7	26.0	189	277	4	282	289	479	77	0	47	47	15.7	84	45	-13	28	506	60.0	47.5	45.7	203.0	13.6	160	102.9
11	12	77	11/11	14:51:59	222	383	382.8	385.4	368.7	26.0	190	278	4	282	290	478	77	0	47	47	15.7	86	45	-13	26	507	60.2	4[illegible]	45.8	203.0	10.6	104	102.7
12	12	77	11/11	14:51:59	221	383	382.5	385.3	369.2	25.9	188	278	4	282	289	477	77	0	46	47	15.5	85	45	13	28	506	60.2	47.[illegible]	46.0	202.5	13.4	161	103.2
13	12	77	11/11	14:51:59	221	383	382.6	385.2	368.7	25.9	189	276	4	281	287	479	76	0	47	47	15.6	83	45	-13	27	508	60.2	47.0	45.9	202.5	12.9	161	102.9
14	12	77	11/11	14:51:59	221	383	382.8	384.8	368.7	25.9	189	277	4	282	289	478	77	0	47	47	15.7	85	45	14	27	510	60.1	44.1	45.8	202.5	10.9	186	103.4
20	12	79	11/11	15:12:20	199	383	381.9	383.0	324.1	29.3	104	278	4	283	290	479	77	0	48	48	15.5	85	41	13	100	491	60.1	55.8	54.2	203.0	13.0	91	102.9
21	12	79	11/11	15:12:20	199	383	382.1	382.9	324.1	29.5	103	278	4	282	289	479	76	0	48	48	15.5	85	41	-13	100	490	60.0	57.5	54.2	203.0	13.8	90	103.0
2[illegible]	[illegible]	79	11/11	15:12:20	199	383	382.2	382.7	324.1	29.3	104	278	4	282	270	478	77	0	48	49	15.5	84	41	-13	100	490	60.0	51.6	53.9	202.5	11.0	70	103.1
2	12	79	11/11	15:12:20	198	383	382.3	382.6	324.1	29.3	103	280	4	283	291	479	76	0	49	47	15.5	85	41	-13	100	496	60.2	53.8	54.5	202.5	11.8	92	103.3
24	12	79	11/11	15:12:20	198	383	381.9	382.5	324.1	29.2	104	279	4	283	290	477	76	0	48	49	15.5	85	41	-13	100	496	60.1	54.0	54.4	202.5	11.9	93	103.1
25	13	80	11/13	13:16:17	173	376	376.0	375.6	357.3	13.7	165	216	5	271	233	431	95	0	124	124	17.9	82	36	3	71	753	60.2	47.2	47.0	203.0	12.8	125	103.4
26	13	80	11/13	13:16:17	123	376	376.2	375.5	356.8	14.5	162	217	5	272	233	428	55	0	123	123	18.0	84	36	3	72	751	60.3	46.6	46.2	203.5	12.6	135	102.7
27	13	80	11/13	13:16:17	123	376	376.2	375.5	357.3	14.4	162	218	5	271	213	431	95	0	124	124	18.7	83	36	3	72	751	60.2	47.1	45.9	203.0	13.0	138	103.2
28	13	80	11/13	13:16:17	124	376	376.2	375.6	356.6	14.2	161	217	5	272	213	428	95	-0	124	124	18.5	83	36	3	72	753	60.[illegible]	[illegible]7.0	46.5	203.0	12.5	138	103.4
29	13	80	11/13	13:16:17	124	376	376.2	375.6	357.3	14.1	164	216	5	271	233	427	95	0	125	124	18.5	83	36	3	71	751	60.2	46.4	45.8	202.5	12.5	138	103.6
30	13	0	11/13	13:16:59	125	375	375.5	372.7	357.1	13.8	163	217	4	271	237	429	95	0	125	124	18.5	83	36	3	71	752	60.2	47.4	43.0	193.4	12.7	142	103.2
31	13	81	11/13	13:20:39	130	377	376.2	375.4	350.3	15.3	149	212	5	220	231	427	75	0	131	131	20.3	81	37	5	100	703	60.0	46.3	45.5	203.0	12.7	13[illegible]	104.0
32	13	81	11/13	13:20:39	130	377	376.2	375.5	349.8	14.5	149	217	5	218	231	431	95	0	131	132	18.9	81	37	5	100	704	60.3	48.3	47.5	203.5	12.8	131	103.7
33	13	81	11/13	13:20:39	131	377	376.2	375.7	350.3	14.6	140	214	5	219	231	428	75	0	131	131	19.2	83	37	5	100	705	59.9	47.9	47.0	203.0	12.8	131	103.[illegible]
34	13	81	11/13	13:20:39	131	377	376.2	375.9	350.3	14.6	149	216	5	219	231	427	95	0	132	133	19.1	83	37	5	100	706	60.2	48.2	47.0	203.5	13.1	131	103.8
35	13	81	11/13	13:20:39	132	377	376.2	375.9	350.3	14.4	151	216	5	219	231	427	95	0	131	131	18.8	83	37	5	100	704	59.9	48.3	47.3	203.0	12.8	131	103.8

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Table 7-2. (Cont'd)

[illegible] TAPE DATA UNPROCESSED

TDS- 5000 ppm; Inert control [illegible] (Proprietary)

File	Run	Set	DATE	TIME	Tr	Ts	To	Tf	Tl	Ql	Pl	Pf	Tsup	Pv	Ps	Pu	Mu	Mr	M-	Mf	Mv	is	Iu	*/h	TotZ	kW	Freq	effZ	effZZ	T2	P2	Pd	PfZ
36	13	0	11/13	14:17:04	194	385	382.6	381.6	321.5	14.9	155	184	0	200	231	152	90	2	114	115	15.7	85	41	1	65	670	59.9	42.9	37.9	192.0	10.0	151	103 3
37	13	02	11/13	15:13:10	269	392	391.2	393.4	347.9	30 6	144	266	4	262	276	439	90	0	66	67	24 6	84	41	-13	100	795	60.0	42 0	48.2	202.0	8 7	130	103 3
38	13	02	11/13	15:13 10	260	392	391.5	391.1	347.9	30 5	144	267	5	262	276	438	90	0	67	67	24.7	84	41	-12	100	793	59.9	50.7	47 9	202 0	16 3	130	103 1
39	13	02	11/13	15 13:10	267	392	391.7	392.0	347.9	30 3	144	267	4	262	276	441	91	0	67	68	24.6	84	41	-12	100	794	60.1	59 2	49.0	202 0	19 3	130	103 3
40	13	02	11/13	15:13:10	260	392	391.6	392.5	347 9	30 4	144	266	4	263	276	444	91	0	67	67	24.6	84	41	13	100	790	60.2	45 0	48.4	202 0	10.4	130	103 3
41	13	02	11/13	15 13:10	267	392	391 7	392.3	347.9	30 3	144	267	4	262	276	442	91	-0	68	67	24 7	84	40	-12	100	796	60 0	48.1	49 4	202 5	11 9	37	103 0
42	13	03	11/13	15 14.26	265	391	391.7	391.6	347.9	30.0	144	267	5	262	275	441	90	-0	68	68	24.6	84	40	-11	100	795	60.0	58.7	48.0	202 0	18 9	175	103 6
43	13	03	11/13	15:14:26	265	392	391 5	391.5	347 9	30 1	144	265	5	262	275	436	90	0	66	68	24.7	84	40	-12	100	793	59.8	45.0	48 0	202.0	10.1	125	103 0
44	13	03	11/13	15:14:26	265	391	391.5	391.5	347.9	30 0	144	265	5	262	275	436	89	0	68	68	24 6	83	40	-12	100	795	60 0	44 3	48.3	202 0	9 6	124	103 2
45	13	03	11/13	15:14 26	265	391	391 5	391 4	347 9	30 1	144	265	5	262	275	439	90	-0	68	68	24.6	82	40	12	100	793	60 0	52 9	48.1	202.0	15 1	126	103 2
46	13	03	11/13	15 14 26	265	391	391.7	391.4	347 4	30 0	144	266	5	262	275	441	90	-0	68	68	24 6	82	40	-11	100	792	59 9	55.7	48.2	202.5	16 9	122	102 9
47	13	03	11/13	15:14:26	265	391	391.7	391.4	347.4	29 9	144	267	5	262	275	437	90	-0	68	68	24 5	82	40	-12	100	793	60 0	44.1	48 3	202 5	9 6	132	102 7
48	13	03	11/13	15:14:26	264	391	391.7	391 3	347 9	30.1	144	260	4	262	275	441	90	-0	68	68	24 6	84	40	12	100	794	60 1	47.6	48.4	202 5	11.6	127	103 2
49	13	03	11/13	15:14:26	264	391	391 0	391.2	347 4	30 0	144	266	4	262	275	439	90	-0	68	68	24.6	83	40	-12	100	799	60 2	50.1	48 7	202.5	13.0	126	105 6
50	13	03	11/13	15:14:26	264	391	391 6	391.2	347.4	30 0	145	266	4	262	275	441	90	-0	68	68	24.0	84	40	-11	100	801	60 2	58.1	48 4	202 5	18.4	124	103 4
51	13	03	11/13	15 14.26	264	392	391.6	391 2	347.9	29.8	145	267	4	262	276	439	90	0	69	69	24 5	84	40	11	100	797	60.0	55.4	48.4	202 5	16.6	127	103 5
53	13	04	11/13	15:32 28	324	400	399.9	399 3	364 2	17.7	179	260	4	266	278	444	89	-0	137	137	23 0	84	42	0	100	1005	60.0	43 7	44.9	203.0	11.4	162	103 1
54	13	04	11/13	15 32:28	324	400	399.8	399 3	364 2	17 3	180	261	5	265	278	441	89	-0	136	136	23 0	84	42	7	100	999	60.1	42 2	45 5	203.0	10.1	164	103 2
55	13	04	11/13	15:32 28	324	400	399.8	399.3	364 2	17 5	178	261	5	264	277	445	91	0	137	137	23 2	84	42	8	100	1006	60.1	53.6	45.7	203 0	17 7	156	103 1
56	13	04	11/13	15:32.28	324	400	399.8	399.4	364 2	17.6	178	260	5	265	277	441	90	0	135	135	23.2	84	42	7	100	1004	60.1	45.1	45.8	203 0	11.8	165	103.5
57	13	04	11/13	15:32:28	324	400	399.9	399.3	363 7	17 8	178	250	5	265	277	442	90	-0	134	134	23.3	83	42	7	100	1005	60.2	48.6	46.0	203 0	14 0	156	103 7
58	13	04	11/13	15:32:28	325	400	399 8	399.3	364.2	17.9	178	259	4	266	277	442	90	0	134	134	23.6	83	42	7	100	1000	60.1	48.1	45 4	203.0	14 0	154	102 9
59	13	04	11/13	15:32:28	324	400	399 9	399.3	364 2	17.6	180	259	5	264	277	442	90	-0	135	135	23 4	83	42	7	100	1002	60 1	48 4	45 5	203.0	14.2	161	103 4
60	13	04	11/13	15 32:28	325	400	399.9	399.3	363.7	17 5	180	259	5	265	277	445	90	-0	135	134	23.1	82	42	6	100	999	60.2	42 9	45 9	203.5	10.4	164	103 4
61	13	04	11/13	15:32:28	325	400	399.9	399 3	363.7	18.0	181	257	5	265	277	441	90	-0	133	133	23.8	83	42	7	100	999	60 2	46.7	45.1	203.0	13.3	155	103 1
62	13	04	11/13	15:32:28	325	400	399 8	399 4	364 2	17.6	180	260	5	265	277	441	90	0	134	134	23.2	82	42	7	100	1001	60 1	45 0	45 6	202.5	11 8	168	103 0

The unprocessed data sets were tabulated and averaged (see Appendix P). These tables contain instantaneous data, whereas data logged with a zero set number were data which were averaged and logged automatically by the computer. In most cases, improper data logged automatically was discarded based on inspection of the operating log. The only known bad sample which slipped through the screening process was recorded during Run No. 13 at time 14:17:04 on File No. 36. The operator observed this recording, noted that test conditions were being adjusted and entered "No good" in the operating log (see Figure 2-17). Unfortunately, the bad data sample was retained and appears in the subsequent processed and unprocessed data tabulations and in the final results.

The number of rows of good data presented for 1979 is 84, compared with 67 for 1978 (152-67-1). This comparison is misleading. The 1978 data resulted from an aggressive test program to characterize the performance of the HSE under a wide variety of test conditions. Data were recorded on tape only by direct operator command. During the 182-hour period of continuous operation during May 22 to May 30, only 4 sets or rows of data were recorded on tape because no new performance was being demonstrated, other than durability. The copious printed data logged by the operating program for all tests were not used to supplement the tables in this report nor the data analysis because there was no need to do so. In 1979, on the other hand, data were logged on tape automatically and frequently during periods of overhaul verification, system demonstration, and on 10 days of monitoring for efficiency change while trying to force scale growth with injection of calcium chloride, usually under constant test conditions. Much of these data are uninteresting from the standpoint of performance mapping but influence the data correlation nonetheless. Of the 14 test days in 1979, 11 days and 49 rows of data were of this sort. This distribution of test days shows what was emphasized during the 1979 testing, and stresses the importance the investigators placed on the growth of scale within the expander for a proper evaluation of the machine. The 1979 testing was essential to assess the adequacy of the overhaul and equipment modifications under known field conditions. It also supplemented the 1978 test results with test data for full load and for nearly dry steam feed. Nonetheless, the majority of the performance characteristics presented in this report were determined in 1978.

The 1979 test results were calculated for the averaged data and stored in the special Z matrix (Ref. 4). The results are presented in Table 7-3. The special Z matrix was developed to accommodate all of the test results for 1979 as well as 1978, and also the test results from all subsequent testing in other countries, or elsewhere, as long as the data logging is compatible. This was done to facilitate a comparative analysis of the test results on a compatible basis within the limits of differing test procedures, calibration accuracy, etc. As an example of the application of this data management concept, the results of the 1980 testing by CFE in Mexico are included here.

4. Mexico Testing: 1980

The 1980 testing in Mexico utilized Test Process No. 2 described in Section V.3.b. (see Figure 5-2). The exhaust vapor flow was measured with a

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Table 7-3. 1979 Utah Data, Averaged Sets

1979 UTAH TAPE DATA AVERAGED SETS

Prepared 10/8/80 pm

TDS= 5000 ppm;Inert gasses- wt% of stm (Proprietary)

Z11 FILE

rev	ave	Run	Set	DATE	TIME	Tr	Ts	Te	Tf	T1	Q1	P1	Pf	Tsup	Pv	Ps	Pu	Mw	Mr	Ms	Mf	Mv	Ls	Lw	'/h	Tr%	KW	freq	eff%	eff2%	T2	P2	Pd	PF%
68	1	0	0	10/12	16:59:19	183	416	376.7	376.3	375.3	7.6	202	297	0	304	308	358	100	19	91	110	0.0	84	74	-10	11	185	59.6	34.0	33.8	201.5	12	176	101.7
69	2	0	0	10/12	17:23:44	187	415	377.7	377.5	377.4	-13.0	221	296	0	303	307	358	100	19	93	112	0.0	84	70	-10	7	185	59.8	32.1	32.4	201.5	12	177	102.0
70	3	0	0	10/12	17:36:36	189	415	377.5	376.3	338.2	4.6	115	278	0	304	308	359	100	19	89	107	0.0	83	67	-11	85	181	59.7	35.3	35.4	201.5	12	94	102.7
71	4	0	0	10/12	17:40:57	189	415	376.7	376.5	335.7	4.9	111	297	0	304	308	359	101	19	88	107	0.0	84	67	-11	100	183	59.9	35.3	35.7	201.5	12	93	102.0
72	5	0	0	10/12	17:57:06	191	416	385.6	385.5	370.2	0.7	195	295	0	304	308	360	102	19	114	133	0.0	84	65	-4	30	286	60.1	36.2	36.5	201.5	12	175	105.1
73	6	0	0	10/12	18:06:54	191	416	387.1	386.9	386.7	-15.1	252	295	0	304	300	362	103	19	121	140	0.0	84	64	-3	8	288	60.6	34.0	34.6	201.5	12	201	105.3
74	7	0	0	10/12	18:15:49	192	416	386.3	385.7	351.5	4.2	137	294	0	304	308	358	100	18	113	131	0.0	84	64	-4	100	285	59.6	38.1	38.2	201.5	12	113	104.0
75	8	0	0	10/12	18:47:54	193	417	392.0	391.8	370.3	1.6	193	293	0	305	310	299	112	18	138	156	0.0	84	62	-1	50	376	59.9	37.7	37.5	201.6	12	172	106.4
76	9	0	0	10/12	18:58:11	193	417	393.2	393.0	392.7	-9.2	252	292	0	304	309	299	112	18	144	162	0.0	84	62	0	12	378	60.3	35.9	35.9	201.8	12	213	106.1
77	10	0	0	10/12	19:00:08	194	417	393.5	393.1	392.9	-9.3	253	292	0	305	310	298	113	18	145	162	0.0	84	62	0	12	378	60.3	35.9	35.8	201.8	12	214	105.8
78	11	0	0	10/12	19.12:15	194	416	392.7	392.1	366.6	3.2	166	292	0	304	309	298	117	17	139	157	0.0	84	61	-1	88	382	59.8	38.6	38.3	201.5	12	137	105.9
79	12	0	0	10/12	20:12:17	191	407	406.3	405.9	391.3	1.8	225	295	0	303	310	300	130	0	132	132	0.0	84	53	-9	33	355	60.2	36.9	36.8	201.6	12	200	107.1
80	13	1	0	10/16	11:30:44	145	410	404.4	403.4	369.6	4.3	170	297	0	303	310	511	67	2	83	85	0.0	84	53	-0	70	173	59.8	32.3	32.4	202.0	12	143	101.7
81	14	1	0	10/16	12:30:46	178	410	405.0	404.9	365.0	5.0	163	297	0	301	308	504	66	2	82	84	0.0	84	54	-0	32	174	59.7	32.5	32.7	202.0	12	136	101.6
82	15	1	0	10/16	13:30:47	188	411	407.3	407.0	365.9	5.2	164	297	0	301	308	501	66	1	81	83	0.0	84	53	-1	31	173	59.7	32.1	32.4	201.9	12	130	101.3
83	16	1	0	10/16	14:30:49	191	411	408.0	407.2	366.0	5.2	164	297	0	302	308	500	66	1	81	82	0.0	83	53	-1	32	173	59.7	32.4	32.6	202.0	12	137	101.7
84	17	1	0	10/16	15:30:50	193	411	407.6	407.1	363.9	5.4	159	296	0	299	306	498	67	1	80	82	0.0	84	52	-1	33	172	59.6	32.3	32.8	202.0	12	134	101.1
85	18	1	0	10/16	16:30:51	193	411	407.7	406.9	363.2	5.5	157	297	0	302	308	502	67	1	83	84	0.0	83	51	-0	35	173	59.8	31.7	32.0	202.0	12	133	101.1
rev	ave	Run	Set	DATE	TIME	Tr	Ts	Te	Tf	T1	Q1	P1	Pf	Tsup	Pv	Ps	Pu	Mw	Mr	Ms	Mf	Mv	Ls	Lw	'/h	Tr%	KW	freq	eff%	eff2%	T2	P2	Pd	PF%
86	19	1	0	10/16	17:21:39	193	411	407.9	406.9	367.0	5.1	165	297	0	302	308	530	71	1	82	83	0.0	84	50	-2	32	175	61.7	31.9	32.4	202.0	12	139	101.7
87	20	1	0	10/16	17:30:54	93	411	408.7	407.5	364.4	5.4	161	297	0	302	308	481	63	1	82	83	0.0	83	50	1	34	181	58.2	32.0	33.4	202.0	12	136	100.9
88	21	2	0	10/17	17:45:15	149	411	408.5	407.7	366.6	5.2	164	297	1	303	309	512	64	1	79	80	0.0	84	56	1	56	175	59.6	33.2	33.5	201.5	12	173	101.8
89	22	2	0	10/17	18:45:17	174	412	409.5	408.9	374.6	4.4	182	298	1	304	309	510	64	1	76	77	0.0	84	55	-1	50	176	59.7	33.9	34.3	201.5	12	136	101.1
90	23	2	0	10/18	12:11:45	138	412	408.7	408.3	362.4	5.8	156	298	0	304	309	523	64	1	79	80	0.0	84	72	-1	35	173	60.1	32.5	33.1	201.5	11	130	102.5
91	24	2	0	10/18	13:11:47	166	412	409.7	409.0	362.2	5.9	156	298	0	304	308	519	64	1	80	81	0.0	84	72	-0	36	176	60.2	32.0	33.0	201.5	12	130	101.0
92	25	2	0	10/18	14:11:49	177	412	410.2	409.4	368.4	5.2	169	299	0	304	309	515	64	1	79	79	0.0	84	72	-1	29	175	60.1	32.7	33.0	201.4	12	141	100.9
93	26	2	0	10/18	15:11:51	182	412	410.2	409.5	370.8	4.9	174	298	0	304	309	515	63	1	78	78	0.0	84	72	-1	27	174	60.1	33.0	33.3	201.5	12	140	101.3
94	27	2	0	10/18	16:11:53	185	412	409.7	409.2	371.9	4.7	176	299	0	304	310	518	62	1	80	81	0.0	83	73	0	26	174	60.1	31.7	32.1	201.1	11	150	103.5
95	28	2	0	10/18	17:11:54	184	412	410.3	409.6	369.6	5.0	172	299	0	305	310	518	62	1	80	80	0.0	83	73	0	28	176	60.1	32.4	32.6	201.1	12	147	105.4
96	29	3	0	10/20	11:09:48	111	414	411.6	410.9	367.9	5.6	165	302	0	308	316	526	61	1	79	79	0.0	84	89	-0	31	176	60.0	32.7	33.3	201.5	12	14	106.4
97	30	3	0	10/20	12:09:49	125	413	411.2	411.0	371.3	5.2	173	303	0	310	318	526	61	1	78	79	0.1	84	89	0	27	174	60.1	32.3	32.5	201.6	12	14	105.3
98	31	3	0	10/20	13:09:51	14[illegible]	414	412.0	411.3	362.8	6.4	153	302	0	310	318	513	64	0	78	78	0.1	90	90	-1	37	177	59.9	33.2	33.8	201.9	12	13	104.1
99	32	3	0	10/20	14:09:52	159	414	412.7	412.2	360.8	6.4	154	301	0	309	317	508	65	0	78	79	0.0	84	89	-1	38	173	59.9	32.4	32.9	201.7	12	13	102.8
100	33	4	0	10/23	12:28:31	117	409	408.6	408.1	391.0	2.1	224	292	0	298	305	345	120	0	144	144	0.0	84	76	-2	38	389	57.7	36.0	36.2	202.0	12	14	105.4
101	34	4	0	10/23	13:28:40	166	409	408.6	408.2	393.3	1.8	231	291	0	298	306	341	121	0	141	141	0.0	84	71	-3	40	395	59.9	37.5	37.4	202.0	12	16	104.9
102	35	4	0	10/23	41:28:41	204	409	408.5	408 2	396.0	1.4	239	294	0	299	306	340	121	0	138	138	0.0	84	67	-4	41	394	59.9	38.1	38.1	202.0	12	15	103.5
103	36	4	0	10/23	15:28:42	247	409	408.9	408.3	394.3	1.7	234	293	0	299	306	338	121	0	138	138	0.0	84	62	-4	48	394	59.9	38.1	38.1	202.0	12	16	103 4
104	37	4	0	10/23	16:28:43	286	409	409.3	408.6	395.1	1.6	236	294	0	301	307	340	120	0	137	137	0.0	83	57	-4	50	395	59.9	38.1	38.1	202.0	12	16	103.5
105	38	4	0	10/23	17:29:16	300	409	409.2	408.8	394.5	1.7	234	293	0	300	307	338	120	0	137	137	0.0	84	52	-4	51	392	59.8	37.9	37.9	202.2	12	16	102.2
106	39	5	0	10/25	17:24:52	339	410	409.9	409.2	399.7	1.0	251	292	0	301	300	298	135	0	155	155	0.0	84	92	4	31	444	60.1	38.0	37.0	200.9	12	15	102.2
107	40	5	0	10/25	18:11:31	381	413	411.6	409.8	401.7	0.8	257	286	0	303	309	299	131	6	199	205	0.0	84	89	9	54	613	59.7	38.0	37.7	201.1	12	15	102.4
108	41	5	0	10/25	19:11:32	391	412	411.8	409.9	402.2	0.8	257	286	0	302	310	300	129	7	199	206	0.0	84	86	10	52	610	59.9	38.1	37.3	201.1	12	16	102.5

Table 7-3. (Cont'd)

1979 UTAH TAPE DATA AVERAGED SETS

TDS= 5000 ppm;Inert gasses= wt% of <in (Proprietary)

ZII FILE

row	ave	Run	Set	DATE	TIME	Tr	Ts	To	Tf	T1	Q1	P1	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	'/h	Tr'%	KW	freq	eff%	eff2%	T2	P2	Pd	PF%
109	42	5	0	10/25	19:53:25	392	413	411.9	410.1	402.2	0.8	258	286	0	302	310	299	129	8	195	202	0.0	83	84	9	52	609	59.8	39.6	37.8	201.1	13	15	102.4
110	43	6	0	10/27	11:09:31	102	407	406.4	406.1	400.7	10.1	254	286	3	295	302	441	100	0	102	102	10.9	85	85	[illegible]	45	543	60.0	38.6	38.0	201.0	12	14	103.8
111	44	6	0	10/27	12:09:33	137	407	406.2	405.9	400.1	10.1	253	286	3	294	301	440	102	0	101	101	10.8	85	81	-7	51	541	59.9	38.9	38.3	200.9	12	14	103.2
112	45	6	0	10/27	13:09:35	161	407	406.3	405.8	399.4	10.0	252	285	3	294	300	440	101	0	102	102	10.8	84	77	-7	52	542	60.0	38.9	38.1	200.8	12	13	103.7
113	46	6	0	10/27	14:10:37	175	406	406.4	405.7	399.2	10.1	252	285	3	293	299	439	98	0	100	100	10.7	84	74	-6	52	540	60.0	39.3	38.5	200.6	12	14	103.2
114	47	6	0	10/27	15:09:38	180	407	406.4	406.0	399.4	10.2	252	286	3	294	300	437	92	0	101	101	10.8	84	70	-4	51	545	60.1	39.2	38.5	200.6	12	16	103.3
115	48	6	0	10/27	16:09:40	183	407	406.9	406.1	400.3	10.1	254	287	3	296	301	439	92	0	101	101	10.7	84	66	-4	50	543	60.0	39.0	38.4	200.5	12	14	103.4
116	49	6	0	10/27	17:09:41	185	406	406.0	405.5	400.3	9.9	255	287	3	296	301	440	92	0	101	101	10.7	84	62	-4	50	542	60.1	39.0	38.4	200.6	12	15	103.3
117	50	6	0	10/27	18:09:43	183	411	410.5	409.0	400.9	10.7	256	288	3	298	304	440	97	0	99	99	11.0	83	59	-5	50	545	60.0	38.6	38.0	200.7	12	14	103.4
118	51	7	0	10/28	11:56:20	131	404	402.7	402.0	401.4	25.0	257	288	3	287	296	540	47	0	52	52	17.6	84	52	-3	38	537	60.0	37.7	37.2	200.0	12	14	102.5
119	52	7	0	10/28	12:56:20	157	403	401.2	399.7	400.2	25.1	255	285	3	283	293	539	47	0	52	53	17.9	84	51	-2	39	541	59.9	37.7	37.2	199.8	12	16	103.6
120	53	7	0	10/28	13:56:23	171	404	402.4	401.0	401.5	25.4	258	288	3	287	296	540	47	0	51	51	17.7	84	50	-2	38	539	60.0	37.8	37.3	199.6	12	13	103.2
121	54	7	0	10/28	14:56:25	177	401	399.9	399.6	401.5	25.2	258	288	3	288	297	542	47	0	51	51	17.7	83	49	2	37	540	60.2	38.1	37.6	199.7	12	15	103.2
122	55	9	0	11/03	13:18:36	136	361	360.5	353.0	387.3	99.0	218	284	3	275	290	277	-0	0	0	0	26.4	84	62	0	36	533	60.3	35.5	35.1	198.8	12	13	103.9
123	56	9	0	11/03	13:26:00	135	357	357.3	349.9	396.4	98.0	242	284	3	275	290	278	-0	0	0	0	26.8	84	63	0	30	533	60.1	34.0	33.5	198.8	12	14	104.2
124	57	9	0	11/03	13:37:41	136	352	350.2	344.4	352.1	99.7	141	286	3	277	297	279	-0	0	0	0	26.0	84	63	0	92	532	60.2	42.0	41.3	198.8	12	[illegible]	[illegible]
125	58	9	0	11/03	14:37:42	97	401	399.9	400.1	370.0	3.8	172	294	0	301	305	533	63	0	87	87	0.0	83	67	2	27	180	60.3	33.1	33.1	200.7	12	15	99.9
126	59	9	0	11/03	15:40:22	97	390	389.4	389.4	361.6	3.5	155	292	0	300	305	456	87	0	94	94	0.0	84	66	-4	35	184	59.9	34.7	34.5	201.0	12	13	99.9
127	60	9	0	11/03	16:40:23	131	403	402.8	401.4	366.5	4.4	165	295	0	303	308	456	87	0	87	87	0.0	84	60	-6	31	184	60.1	33.2	33.5	200.8	11	13	99.6
128	61	10	0	11/04	11:47:36	95	405	405.0	404.0	366.6	4.8	164	293	0	300	306	467	86	0	84	84	0.0	84	57	-7	31	181	60.1	33.2	33.5	201.0	12	13	99.3
129	62	11	0	11/06	11:59:46	94	411	410.8	409.6	346.1	7.1	137	294	0	297	301	542	51	0	56	56	0.0	84	53	-2	25	69	60.3	24.1	24.5	203.0	12	9	[illegible]
130	63	11	0	11/06	12:59:47	132	411	411.0	409.7	346.7	7.0	139	293	0	296	300	534	50	0	56	56	0.0	84	51	-2	62	68	60.0	23.7	24.1	203.0	12	9	.3
row	ave	Run	Set	DATE	TIME	Tr	Ts	To	ff	T1	Q1	P1	Pf	Tsup	Pv	Ps	Pw	Mw	Mr	Ms	Mf	Mv	Ls	Lw	'/h	Tr'%	KW	freq	eff%	eff2%	T2	P2	Pd	r.%
131	64	11	0	11/06	13:59:40	158	411	410.5	409.6	354.8	5.8	157	293	0	295	299	535	51	0	54	54	0.0	84	48	-3	48	70	60.3	24.6	25.0	202.9	12	10	82.0
132	65	11	0	11/06	14:59:50	170	406	405.6	404.6	355.7	4.7	166	293	0	295	299	537	51	0	55	55	0.0	84	45	-3	45	69	60.4	24.9	25.4	203.0	12	9	82.4
133	66	11	0	11/06	17:01:18	180	410	409.4	408.5	351.3	6.2	149	295	0	297	301	529	51	0	51	51	0.0	84	34	-4	62	68	60.0	26.3	26.0	203.0	12	11	80.9
134	67	11	0	11/06	18:01:48	179	409	408.1	407.3	340.9	7.3	179	296	0	299	305	535	51	0	53	53	0.0	85	29	-3	60	69	60.3	26.7	27.2	203.3	12	9	83.7
135	68	11	0	11/06	19:04:06	179	409	408.2	407.6	353.1	6.1	148	286	0	290	295	542	37	0	52	52	0.0	83	29	1	52	62	60.6	24.4	24.9	207.3	12	7	77.5
136	69	11	0	11/06	19:14:06	179	409	408.4	407.5	344.1	7.0	134	295	0	298	304	553	38	0	52	52	0.0	85	31	1	65	63	60.3	25.2	25.8	203.1	12	9	80.7
137	70	12	73	11/11	13:23:17	310	408	407.5	407.0	370.7	3.8	189	284	0	296	300	292	141	0	170	171	0.0	85	55	-2	36	518	60.1	41.7	41.5	204.0	13	173	102.9
138	71	12	0	11/11	13:25:38	321	407	407.1	406.9	367.9	4.1	182	287	0	294	297	291	136	0	171	171	0.0	85	55	0	38	518	60.0	40.8	39.1	197.8	12	169	103.0
139	72	12	74	11/11	13:39:32	347	407	407.0	406.5	331.6	8.3	113	282	0	294	299	290	133	0	170	170	0.0	84	55	1	98	510	59.9	46.3	45.3	204.0	13	99	103.1
140	73	12	0	11/11	13:41:26	349	407	407.0	406.7	331.4	8.4	112	283	0	295	299	291	132	0	169	169	0.0	85	55	1	99	506	59.8	45.6	45.2	203.8	13	97	102.9
141	74	12	75	11/11	14:05:54	348	393	393.0	394.1	360.1	15.0	186	285	4	287	292	284	131	-0	81	80	11.9	85	50	-23	29	505	60.1	42.9	43.6	202.9	12	167	103.1
142	75	12	76	11/11	14:23:44	289	394	394.4	393.2	375.2	16.2	105	285	4	289	294	481	76	0	93	93	9.7	85	48	-0	100	485	60.0	50.4	50.4	203.0	12	92	102.9
143	76	12	0	11/11	14:41:28	240	388	388.0	387.5	364.9	23.6	179	275	4	282	289	484	78	0	48	49	13.7	85	47	13	29	498	60.5	48.7	48.8	202.8	12	161	103.4
144	77	12	77	11/11	14:5[illegible]:59	221	383	382.7	385.2	360.8	26.0	189	277	4	282	289	478	77	0	47	47	15.7	85	45	-13	27	508	60.2	45.5	45.3	202.7	12	170	103.0
145	78	12	79	11/11	15:1[illegible]:20	199	383	382.1	382.7	324.1	29.3	104	279	4	283	290	478	76	0	48	48	15.5	85	41	-11	100	492	60.1	53.9	53.6	202.7	12	91	103.1
146	79	13	80	11/13	13:16:17	124	376	376.1	375.5	357.1	14.2	163	217	5	221	233	429	95	-0	124	124	18.5	83	36	3	72	752	60.2	46.6	45.9	203.0	13	135	103.3
147	80	13	0	11/13	13:16:59	125	375	375.5	372.7	357.1	13.8	163	217	4	221	233	429	95	-0	125	124	18.5	83	36	3	71	752	60.2	47.0	42.6	193.4	13	142	103.2
148	81	13	81	11/13	13:20:39	131	377	376.2	375.7	350.2	14.7	149	215	5	219	231	428	95	0	131	132	19.3	83	37	5	100	784	60.1	47.4	46.5	203.2	13	131	103.0
149	82	13	0	11/13	14:17:04	194	385	382.6	381.6	321.5	14.9	155	184	8	208	231	352	90	2	114	115	16.7	85	41	1	65	678	59.9	42.5	37.5	182.0	11	151	113.3
150	83	13	82	11/13	15:13:10	268	392	391.5	392.8	347.9	30.4	144	267	4	262	276	441	90	0	67	67	24.6	84	40	12	100	795	60.0	49.9	47.8	202.1	13	130	103.2
151	84	13	83	11/13	15:14:26	265	391	391.6	391.4	347.7	30.0	144	266	5	262	275	439	90	-0	68	68	24.6	83	48	12	100	795	60.0	50.9	47.9	202.3	14	126	103.4
152	85	13	84	11/13	15:32:20	324	400	399.8	399.3	364.1	17.6	179	260	5	265	277	443	90	-0	135	135	23.4	83	42	7	100	1007	60.[illegible]	46.2	45.2	203.0	13	161	103.2
153	86	13	0	11/13	13:16.59	125	375	375.5	372.7	357.1	13.8	163	217	4	221	233	429	95	-0	125	124	18.5	83	36	3	71	752	60.2	47.0	42.6	193.4	13	142	103.2

sharp-edged orifice with flange tapes, and the exhaust liquid was measured with a Cipolletti trapezoidal weir. Standard orifice and weir equations were used.

The data for the 1980 testing in Mexico was logged by CFE on two 17-inch printers, and on computer tape by the operating computer using the same data system that was used in Utah. These data logs are on file in Mexico. In addition, at approximately the same time that steady-state data were logged on tape by CFE, data were logged by JPL on tape by the second, or analysis, computer connected into the system. It is the data logged by JPL which are reported here, as discussed in Section II.E.2.c. Some of these data were averaged by the computer and then logged as averaged sets, and some were logged as sets of instantaneous data samples. The instantaneous data were tabulated and averaged for examination and processing exactly as was done with the Utah data. The tabulations and averages are presented in Appendix Q. The test results were then calculated from averaged data and added to the Z matrix.

At the time the JPL data logging began, an endurance run of approximately 984 hours was nearing completion. Thus, the data in Row Nos. 154 through 163 of the Z matrix are endurance run data. During the endurance run the calculated efficiency was observed to increase under approximately constant test conditions. This is consistent with predictions based on an expected disposition of scale within the machine and a resulting decrease in leakage clearances. Inspections of the rotors on occasions during the endurance test and later confirmed that there was some scale build-up in thickness estimated to be not more than 40% of that necessary to close the leakage paths. Subsequent inspection of the process piping revealed white scale deposits in the pipe immediately downstream from the pressure control valve near the wellhead in comparison with the small amount of dark deposits within the machine. Based on the experience in Utah, it was known that from the standpoint of depositing scale within the machine, it would have been better to install the presssure control valve in the bypass in order to allow fluid from the well to flow essentially undisturbed from the wellhead to the expander. Placement of the valve in the bypass was considered and rejected in the interest of avoiding exposing the expander to high wellhead pressures in case of a process mishap. Unfortunately, much of the scale which did form on the rotors was shed again during the 1980 testing.

5. Anomalies

Anomalies occurred in two independent checks of the electrical data acquisition, namely, the comparison of kilowatt and kilowatt hour measurements and the calculation of power factor. As shown by Equations (1) and (2), Section V., the calculated efficiency of the HSE varies almost directly as the alternator output power P_e, which is measured by the kilowatt transducer in the data system. Therefore, the accuracy of the power measurement is very important. The HSE power plant is equipped with a kilowatt hour meter which is independent of the computerized data system. The kilowatt hour meter is equipped with a pulse generator with each pulse corresponding to exactly 1.44 kWh. The pulse generator connects to a counter in the Data Van. This arrangement permits the precise measurement of electrical energy output of the alternator for relatively short time intervals. This measurement can be compared with the energy output determined by integrating the power measured by the data system over the same time interval. The results were anomalous, with the values differing by as much as 3.5% during 1978, 1979 and 1980 (see Figure 7-1). There is some experimental evidence that the discrepancy was temperature dependent, which would not be surprising since the ambient temperature during testing varied from about 15°F to 123°F. This inference is not supported by the manufacturer's specifications on the kilowatt hour meter or the watt tra..sducer. The two instruments were post-calibrated in April 1981 and found to be within the accuracy specifications. The specifications for the watt meter are ±0.1% accuracy at 25°C ± 5°C, an operating range of -20°C to +70°C, with a temperature sensitivity of ± 0.005% per °C. All of the efficiency calculations in this report are based on the kilowatt measurement.

Another means is available to monitor the data system for errors which might creep into the measurement of electrical data. This is the calculation of power factor PF from the measurement of voltage V, current I, and power kW, since

$$PF = kW/VI\sqrt{3} \qquad (15)$$

It was expect?d that the power factor would vary from near u.9 at low load, consisting of the in-plant induction motors and the load bank fan motors, to near unity at high load when the resistive load of the load bank is dominant. The tabulated power factor data of greater than unity in this report are theoretically impossible and have not been explained. The voltage measured for the calculations was produced by ⅽ transformer of commercial rather than instrument grade, and may be the cause. This has not been ir'estigated.

B. QUANTITATIVE TEST RESULTS, CORRELATION AND INTERPRETATION

In this Project, the machine efficiency of the expander was taken as the quantitative index of performance on which to base the evaluation (see Section V.A). The experimental results are presented with the stipulation that the machine was incomplete pending the growth of scale internally, which is necessary to provide the finished internal dimensions. Until these dimensions are achieved, leakage past the rotors occurs in amounts sufficient to degrade the performance. Therefore, the machine was unfinished as tested and the results must be considered as preliminary. For this reason, and because an applications analysis was deleted from the Project, sample utilization curves, such as specific consumption versus power output, are not included in this report. Such curves, based on the experimental data, would not represent the potential performance of the expander and would be misleading. This would be contrary to the JPL commitment to perform an unbiased evaluation. In fact, the test results were highly biased by leakage. However, with the information presented in this report, the geothermal utilization engineer can calculate utilization curves for any field conditions of interest for the range of parameters tested. JPL does not discourage the calculation because in that case the curves are not likely to be used on an uninformed basis.

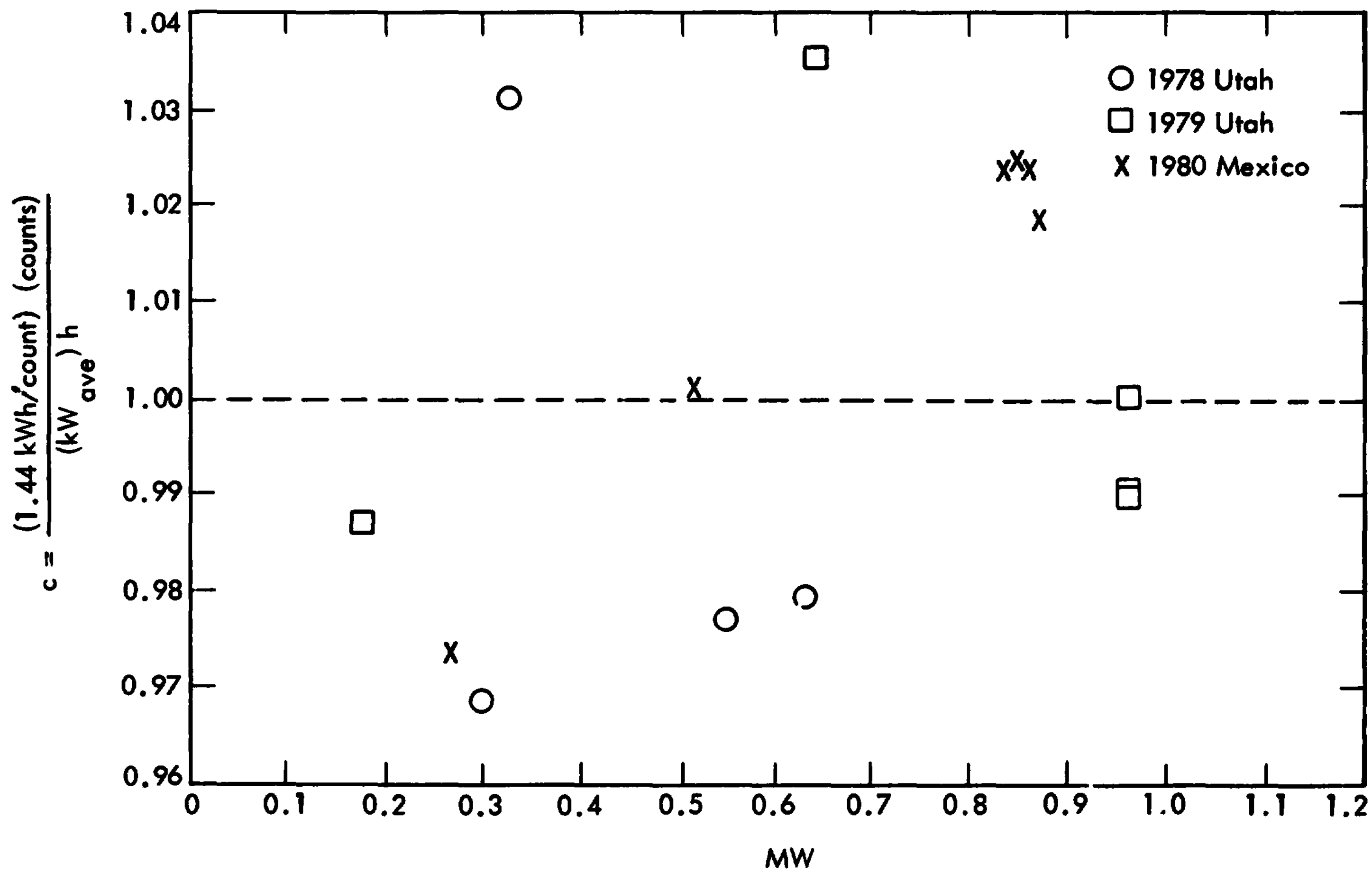

Figure 7-1. Kilowatt Calibration

Of much greater importance than utilization curves are the relationships which characterize the behavior of the expander. Only by proper characterization can the full utilization of the machine eventually be realized. Toward this end, all of the experimental data sets were reported and were used in the analysis to determine the performance characteristics of the machine. That is, preconceived ideas about what the performance characteristics should be were not used to determine which test data were valid. Rather, the validity of the data was determined at the time the data were recorded, thus challenging the data analysis to produce correlations which fit the data, rather than the reverse. In performing the analysis to determine the performance characteristics of the machine, it was recognized that these characteristics are not independent of fluid leakage within the machine, but they are likely to be affected less than utilization curves.

1. Quantitative Test Results

The 1978, 1979 and 1980 test results of the HSE testing in Utah and Mexico were calculated from averaged data sets and are presented in Table 7-4. A few subheadings have been inserted into the table to identify changes in the year, place or some of the specific objectives of the tests. The test conditions are best identified by reading the data because they are mixed and far-ranging. The Utah test conditions included inlet fluid ranging from subcooled liquid to 99% steam, inlet pressure from 84 to 258 psia, exhaust pressures of atmospheric 12 psia and 30 psia, and expander shaft load from idling to 1059 kW, all at 3000-rpm male rotor speed. The Utah test results of machine efficiency versus shaft output power are presented in Figure 7-2. The maximum efficiency achieved in Utah was 53.9%, with the rotors essentially bare.

The Mexico test conditions included inlet steam fraction from 10 to 34%, inlet pressure from 96 to 190 psia, exhaust pressure of atmospheric 14.7 psia and 25 to 40 psia, and expander shaft load from idling to 914 kW, at 3000 and 4000-rpm male rotor speed. The Mexico data logged by JPL are included here to emphasize the importance of scale deposits within the HSE for an evaluation of its performance, as well as to demonstrate the compatibility of the data treatment. (Discussion of the 4000-rpm data and inclusion of the Mexico 1981 vacuum exhaust test data are outside the scope of this report. For a report of these subjects, including accuracy, process and test details, etc., refer to CFE.) The 1980 Mexico test results of machine efficiency versus shaft output power are presented as circles in Figure 7-3, shown along with the Utah test results. The efficiency improvement attributable to scale growth on the rotors and case interior can be clearly seen. The maximum efficiency achieved was 62.0%. Efficiencies in the range of 49 to 50% were calculated and displayed by the data system in Mexico before the scale growth occurred. These early data were not logged by JPL but are available from CFE.

Table 7-4 includes inlet enthalpy tabulated as H1, specific energy output in kilowatt hours per 1000 pounds of fluid, tabulated as kWs/kM, shaft output power kWs of the HSE, and electrical output kW of the alternator. The first two are parameters often used with turbines and were occasionally requested by visitors

Table 7-4. 1978, 1979 and 1980 Test Results

1978, 1979 & 1980 RESULTS

MAY 11, 1981
CALCULATED FROM AVERAGED DATA SETS

rev	ave	Run	Set	DATE	TIME	P1	Q1	H1	kWs/kM	kWs	kW	eff%	effT2%	effPd%	P2	Thr%	eff:E/C
	9	102	2	04/06	0:00:00	109.8	1.8	319.7	1.12	122	76	25.5	25.1	0.0	12.0	28	0.89
2	10	103	3	04/06	0:00:00	109.8	1.0	313.0	1.23	181	135	30.3	29.8	0.0	12.0	38	0.90
3	11	104	4	04/06	0:00:00	120.4	1.2	321.9	1.49	230	183	32.6	32.4	0.0	11.9	41	0.91
4	12	105	5	04/06	0:00:00	104.1	2.8	324.7	1.80	345	297	39.3	38.6	0.0	12.0	88	0.93
5	13	106	6	04/06	0:00:00	120.7	2.5	337.8	2.03	394	344	37.4	37.2	0.0	11.8	68	0.88
6	15	108	8	04/20	0:00:00	125.3	4.8	355.9	2.73	321	273	43.1	42.2	0.0	11.9	56	1.00
7	16	109	9	05/03	18:07:20	111.7	1.7	319.9	1.76	394	345	40.9	39.4	0.0	12.4	87	0.93
8	17	110	10	05/03	18:16:40	112.8	1.5	319.6	1.77	394	345	41.1	39.6	0.0	12.4	85	0.94
9	18	111	11	05/03	19:07:40	105.6	2.9	326.3	1.93	392	343	41.8	40.5	0.0	12.3	95	0.95
10	19	112	12	05/03	19:35:20	107.7	2.7	326.0	1.94	392	343	42.1	40.8	0.0	12.3	92	0.96
11	20	113	13	05/03	19:47:41	147.8	-2.2	325.2	1.92	390	341	41.0	40.0	0.0	12.3	41	0.98
12	21	114	14	05/03	19:59:21	138.5	0.0	322.3	1.85	391	341	40.9	39.8	0.0	12.3	51	0.97
13	22	115	15	05/04	17:56:20	126.0	-1.0	313.6	1.61	399	350	40.2	38.3	0.0	12.6	63	0.92
14	23	116	16	05/04	18:41:20	115.3	0.1	308.9	1.45	404	354	39.1	36.9	0.0	12.8	81	0.88
15	24	117	17	05/04	19:09:21	113.5	-1.0	305.4	1.26	411	361	36.6	33.8	0.0	13.2	85	0.81
16	25	118	18	05/08	15:38:00	155.3	8.4	404.2	3.80	380	330	41.3	40.6	0.0	12.1	45	1.03
17	26	119	19	05/08	19:15:01	95.9	16.9	444.4	4.60	382	333	46.2	45.3	0.0	12.1	97	1.06
18	27	120	20	05/08	19:21:00	95.4	16.9	444.3	4.58	382	333	46.3	45.2	0.0	12.2	98	1.06
19	28	121	21	05/08	19:22:00	95.2	17.0	444.8	4.60	382	333	46.2	45.4	0.0	12.1	98	1.06
20	29	122	22	05/12	11:15:30	96.2	10.5	387.3	3.30	280	232	44.8	44.1	0.0	12.2	72	1.14
21	30	123	23	05/12	12:20:00	89.1	15.1	423.4	3.95	279	231	45.0	44.4	0.0	12.1	77	1.14
22	31	124	24	05/12	12:49:00	87.7	19.9	466.1	4.77	278	230	45.0	44.3	0.0	12.1	77	1.14
23	32	125	25	05/12	12:51:00	87.5	20.0	466.6	4.78	279	231	45.1	44.3	0.0	12.1	78	1.14
24	33	126	26	05/12	13:21:30	84.7	24.6	505.7	5.49	277	229	45.2	44.4	0.0	12.1	80	1.14
25	34	127	27	05/12	13:26:00	84.3	24.7	506.7	5.51	277	229	45.3	44.5	0.0	12.1	80	1.14
26	35	128	28	05/12	14:05:00	108.7	5.2	348.8	2.49	279	231	43.3	42.6	0.0	12.2	63	1.11
27	36	129	29	05/12	14:08:00	109.3	5.2	349.3	2.49	279	231	43.2	42.4	0.0	12.2	62	1.11
28	37	130	30	05/13	10:40:20	99.8	9.9	385.0	3.45	361	312	47.2	46.2	0.0	12.2	88	1.11
29	38	131	31	05/13	10:44:20	101.0	9.7	383.9	3.43	356	308	46.9	45.9	0.0	12.2	86	1.11
30	39	132	32	05/13	11:07:00	92.6	15.0	425.1	4.31	360	311	48.0	47.1	0.0	12.1	100	1.12
31	40	133	33	05/13	11:11:20	91.9	15.6	429.9	4.42	357	308	48.2	47.3	0.0	12.2	100	1.13
32	41	134	34	05/14	10:36:00	134.7	9.8	405.2	4.14	478	427	46.3	45.2	0.0	12.2	71	1.04
33	42	135	35	05/14	10:41:20	135.3	9.7	404.9	4.15	474	423	46.3	45.2	0.0	12.2	70	1.04
34	43	136	36	05/14	11:23:20	128.5	19.8	489.3	6.19	476	425	46.7	45.7	0.0	12.1	70	1.05
35	44	137	37	05/14	11:34:05	127.6	20.1	492.0	6.27	474	424	46.8	45.9	0.0	12.1	71	1.05
36	45	138	38	05/14	13:36:00	139.3	15.2	455.1	5.58	576	524	47.7	46.6	0.0	12.2	80	1.03
37	46	139	39	05/14	13:40:20	140.3	15.3	456.3	5.58	573	520	47.2	46.3	0.0	12.1	80	1.03
38	47	140	40	05/15	11:18:00	155.0	9.9	417.0	4.46	690	635	45.3	44.0	0.0	12.3	87	0.97
39	48	141	41	05/15	11:20:21	156.6	9.8	417.1	4.48	687	632	45.5	44.2	0.0	12.4	85	0.98
40	49	142	42	05/15	11:56:40	135.8	19.8	492.9	6.44	643	589	47.2	46.0	0.0	12.2	97	1.01
41	50	143	43	05/15	11:59:00	136.0	19.7	492.0	6.41	643	589	47.0	45.8	0.0	12.2	97	1.00
42	51	144	44	05/15	13:23:20	170.5	5.7	388.1	3.49	812	754	43.4	41.0	0.0	13.3	97	0.91

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Table 7-4. (Cont'd)

1978, 1979 & 1980 RESULTS

CALCULATED FROM AVERAGED DATA SETS

row	ave	Run	Set	DATE	TIME	P1	Q1	H1	kWs/kW	kWs	kW	eff%	effT2%	effPd%	P2	Thr%	eff:E/C
43	52	145	45	05/19	16:09:30	140.8	16.4	466.3	2.50	220	173	34.3	32.9	0.0	31.2	62	0.90
44	53	146	46	0[illegible]9	16:13:30	118.2	16.8	457.3	2.28	220	173	37.9	36.0	0.0	33.2	96	0.98
45	54	147	47	05/20	13:35:01	143 2	14.9	454.0	4.54	385	335	43.0	42.0	0.0	15.3	52	1.01
46	55	148	48	05/20	13:37:31	142.7	15.0	454.5	4.55	385	335	43.0	42.0	0.0	15.3	52	1.01
Elevated Backpressure P2																	
47	56	149	49	05/20	14:96:00	143.0	19.2	491.7	4.10	386	337	45.9	44.2	0.0	27.8	79	1.01
48	57	150	50	05/20	14:17:30	154.2	20.1	504.8	4.41	387	338	44.4	42.9	0.0	27.1	65	0.98
49	58	151	51	05/20	14:18:31	153.2	20.2	504.8	4.39	387	338	44.4	43.0	0.0	27.2	67	0.98
50	59	152	52	05/20	14:40:03	159.0	15.1	463.4	3.52	394	345	45.2	43.4	0.0	30.1	72	0.99
51	60	153	53	05/20	14:44:00	159.8	15.1	463.7	3.54	391	342	45.1	43.4	0.0	29.8	70	0.99
52	61	154	54	05/20	15:05:15	155.2	10.2	419.5	2.77	397	348	46.7	45.0	0.0	30.4	80	1.01
53	62	155	55	05/20	15:07:45	158.8	10.1	420.5	2.82	399	349	46.7	44.8	0.0	30.3	77	1.01
54	63	156	56	05/20	15:52:30	176.6	4.9	384.3	2.32	393	344	45.2	43.7	0.0	27.0	62	0.99
55	64	157	57	05/20	15:55:55	169.9	5.3	384.4	2.30	398	348	45.5	44.0	0.0	27.3	67	0.99
High Inlet Quality Q1																	
56	65	158	58	05/21	21:08:29	122.7	23.0	514.5	6.83	337	288	47.5	46.6	0.0	12.1	50	1.19
57	66	159	59	05/21	21:26:54	136.4	62.7	867.1	13.49	341	292	39.9	39.2	0.0	12.1	38	1.01
58	67	160	60	05/21	21:29:14	128.7	77.0	990.3	16.58	342	293	42.0	41.2	0.0	12.1	40	1.06
59	68	161	61	05/21	21:33:00	126.8	42.4	686.3	9.10	340	291	38.7	38.0	0.0	12.1	42	0.97
60	69	162	62	05/21	21:36:19	131.4	44.5	706.7	9.93	344	296	40.0	39.1	0.0	12.1	41	1.00
61	70	163	63	05/21	21:40:42	136.0	41.9	685.7	9.47	338	289	39.4	38.6	0.0	12.1	38	1.00
62	71	164	64	05/21	21:53:18	110.4	62.4	856.2	12.54	333	284	41.0	40.2	0.0	12.1	51	1.00
63	72	165	65	05/21	21:55:30	108.0	62.5	856.1	12.49	330	281	41.2	40.4	0.0	12.1	52	1.01
64	73	166	66	05/24	11:07:00	132.3	5.1	362.8	2.79	342	294	41.5	40.9	0.0	12.0	53	1.03
65	74	167	67	05/24	19:17:00	145.7	4.3	363.5	2.80	340	291	40.8	40.1	0.0	12.0	44	1.03
66	75	168	68	05/26	17:25:00	129.6	4.8	359.2	2.77	338	289	42.6	41.9	0.0	12.0	53	1.06
67	76	169	69	05/26	18:10:27	124.7	5.2	359.5	2.92	335	287	45.0	44.3	0.0	12.0	56	1.11
1979: Overhaul Confirmation, Performance Survey, and Scale Deposit Attempts																	
68	169	0	0	10/12	16:59:19	202.2	-7.6	346.3	2.05	225	185	34.0	33.8	33.6	12.0	11	1.05
69	170	0	0	10/12	17:23:44	220.7	-13.0	348.5	2.01	225	185	32.1	32.4	32.1	11.6	7	1.01
70	171	0	0	10/12	17:36:36	114.8	4.6	347.6	2.07	222	181	35.3	35.4	36.8	11.8	85	0.99
71	172	0	0	10/12	17:40:57	110.8	4.9	347.8	2.08	223	183	35.3	35.7	36.7	11.6	100	0.99
72	173	0	0	10/12	17:57:06	195.2	0.7	357.3	2.46	328	286	36.2	36.5	36.4	11.7	30	1.00
73	174	0	0	10/12	18:06:54	251.7	-15.1	358.4	2.36	330	288	34.8	34.6	34.7	12.0	8	1.00
74	175	0	0	10/12	19:15:49	136.5	4.2	357.5	2.49	327	285	38.1	38.2	39.4	11.8	100	0.97
75	176	0	0	10/12	18:47:54	193.4	1.6	364.1	2.68	420	376	37.7	37.5	38.1	12.0	50	0.96
76	177	0	0	10/12	18:58:11	252.3	-9.2	364.9	2.60	421	378	35.9	35.9	35.9	12.0	12	0.97
77	178	0	0	10/12	19:00:08	252.9	-9.3	365.1	2.59	422	378	35.9	35.8	35.9	12.0	12	0.97
78	179	0	0	10/12	19:12:15	165.5	3.2	364.4	2.71	425	382	38.6	38.3	39.6	12.0	88	0.93
79	180	0	0	10/12	20:12:17	225.2	1.8	379.2	3.02	398	355	36.9	36.8	37.3	11.9	33	1.01
80	182	1	0	10/16	11:30:44	170.2	4.3	376.4	2.52	213	173	32.3	32.4	33.2	12.0	28	1.00
81	183	1	0	10/16	12:30:46	162.7	5.0	378.1	2.56	215	174	32.5	32.7	33.5	11.9	32	0.99
82	184	1	0	10/16	13:30:47	163.7	5.2	380.3	2.58	213	173	32.1	32.4	33.0	11.7	31	0.99
83	185	1	0	10/16	14:30:49	163.7	5.2	380.6	2.60	214	173	32.4	32.6	33.3	11.8	32	0.99
84	186	1	0	10/16	15:30:50	158.9	5.4	380.4	2.60	212	172	32.3	32.8	33.2	11.6	33	0.99
85	187	1	0	10/16	16:30:51	157.4	5.5	380.3	2.53	213	173	31.7	32.0	32.7	11.7	35	0.97
86	188	1	0	10/16	17:21:39	164.9	5.1	380.2	2.58	215	175	31.9	32.4	32.7	11.6	32	0.98
87	189	1	0	10/16	17:30:54	160.7	5.4	380.9	2.66	221	181	32.8	33.4	33.8	11.6	34	0.99

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Table 7-4. (Cont'd)

1978, 1979 & 1980 RESULTS

CALCULATED FROM AVERAGED DATA SETS

row	ave	Run	Set	DATE	TIME	P1	Q1	H1	kWs/kM	kWs	kW	eff%	effT2%	effPd%	P2	Thr%	eff:E/C
88	192	2	0	10/17	17:45:15	164.5	5.2	381.1	2.70	215	175	33.2	33.5	35.0	11.6	56	1.02
89	193	2	0	10/17	18:45:17	181.8	4.4	382.4	2.82	216	176	33.9	34.3	35.5	11.6	50	.07
90	196	2	0	10/18	12:11:45	156.0	5.8	381.9	2.66	213	173	32.5	33.1	33.6	11.4	35	1.00
91	197	2	0	10/18	13:11:47	155.8	5.9	382.4	2.66	216	176	32.8	33.0	33.9	11.7	36	0.99
92	198	2	0	10/18	14:11:49	168.9	5.2	382.9	2.70	215	175	32.7	33.0	33.7	11.6	29	1.01
93	199	2	0	10/18	15:11:51	173.8	4.9	383.0	2.74	214	174	33.0	33.3	33.9	11.7	27	1.03
94	200	2	0	10/18	16:11:53	176.4	4.7	382.7	2.65	214	174	31.7	32.1	32.4	11.4	26	1.00
95	201	2	0	10/18	17:11:54	171.8	5.0	383.1	2.69	216	176	32.4	32.6	33.1	11.6	28	1.01
96	203	3	0	10/20	11:09:48	165.0	5.6	384.5	2.73	216	176	32.7	33.0	0.0	11.6	31	1.00
97	204	3	0	10/20	12:09:49	172.6	5.2	385.3	2.71	214	174	32.3	32.5	0.0	11.7	27	1.00
98	205	3	0	10/20	13:09:51	153.3	6.4	386.2	2.78	218	177	33.2	33.8	0.0	11.5	37	1.00
99	206	3	0	10/20	14:09:52	153.8	6.4	386.0	2.71	214	173	32.4	32.9	0.0	11.6	38	0.99
100	211	4	0	10/23	12:28:31	223.7	2.1	381.5	3.00	433	389	36.0	36.2	0.0	11.9	38	0.95
101	212	4	0	10/23	13:28:40	230.7	1.8	381.6	3.12	439	395	37.5	37.4	0.0	12.0	40	0.99
102	213	4	0	10/23	14:28:41	238.8	1.4	381.6	3.18	438	394	38.1	[illegible]	0.0	12.0	41	1.03
103	214	4	0	10/23	15:28:42	234.1	1.7	381.7	3.18	438	394	38.1	38.1	0.0	12.0	48	1.02
104	215	4	0	10/23	16:28:43	236.1	1.6	382.1	3.19	438	395	38.1	38.1	0.0	12.0	50	1.02
105	216	4	0	10/23	17:29:16	234.1	1.7	382.2	3.17	436	392	37.9	37.9	0.0	12.0	51	1.01
106	218	5	0	10/25	17:24:52	250.9	1.0	382.6	3.16	489	444	38.0	37.0	0.0	12.4	31	0.99
107	219	5	0	10/25	18:11:31	256.5	0.8	383.3	3.23	661	613	38.0	37.7	0.0	11.9	54	0.96
108	220	5	0	10/25	19:11:32	257.5	0.8	383.4	3.19	657	610	38.1	37.3	0.0	12.3	52	0.95
109	221	5	0	10/25	19:53:25	257.7	0.8	383.6	3.24	657	609	39.6	37.8	0.0	13.0	52	0.97
110	224	6	0	10/27	11:09:31	254.0	10.1	458.9	5.22	590	543	38.6	38.0	0.0	12.3	45	0.99
111	225	6	0	10/27	12:09:33	252.9	10.1	458.5	5.25	587	541	38.9	38.3	0.0	12.2	51	1.00
112	226	6	0	10/27	13:09:35	252.3	10.0	457.5	5.20	589	542	38.9	38.1	0.0	12.3	52	1.00
113	227	6	0	10/27	14:10:37	252.0	10.1	458.5	5.29	587	540	39.3	38.5	0.0	12.2	52	1.01
114	228	6	0	10/27	15:09:38	251.9	10.2	458.9	5.30	591	545	39.2	38.5	0.0	12.2	51	1.01
115	229	6	0	10/27	16:09:40	254.2	10.1	458.7	5.28	589	543	39.0	38.4	0.0	12.2	50	1.01
116	230	6	0	10/27	17:09:41	255.1	9.9	458.0	5.27	588	542	39.0	38.4	0.0	12.1	50	1.01
117	231	6	0	10/27	18:09:43	256.4	10.7	464.6	5.39	591	545	38.6	38.0	0.0	12.1	50	1.00
118	234	7	0	10/28	11:56:20	257.1	25.0	582.7	8.34	584	537	37.7	37.2	0.0	11.9	38	1.00
119	235	7	0	10/28	12:56:20	254.5	25.1	582.8	8.33	587	541	37.7	37.2	0.0	11.9	39	0.99
120	236	7	0	10/28	13:56:23	258.2	25.4	586.1	8.47	585	539	37.8	37.3	0.0	11.9	38	1.00
121	237	7	0	10/28	14:56:25	258.3	25.2	584.7	8.50	587	540	38.1	37.6	0.0	12.0	37	1.01
122	246	9	0	11/03	13:18:36	217.8	99.0	1191.1	21.63	579	533	35.5	35.1	0.0	11.7	36	0.96
123	247	9	0	11/03	13:26:00	242.5	98.8	1191.2	21.35	579	533	34.0	33.5	0.0	11.8	30	0.95
124	248	9	0	11/03	13:37:41	140.7	99.7	1190.9	21.96	579	532	42.0	41.3	0.0	11.8	92	1.01
125	249	9	0	11/03	14:37:42	172.0	3.8	372.9	2.54	220	180	33.1	33.1	0.0	11.7	27	1.02
126	250	9	0	11/03	15:40:22	155.0	3.5	361.4	2.38	225	184	34.7	34.5	0.0	11.9	35	1.03
127	251	9	0	11/03	16:40:23	165.0	4.4	374.2	2.59	224	184	33.2	33.5	0.0	11.5	31	1.01
128	253	10	0	11/04	11:47:36	164.0	4.8	377.1	2.63	221	181	33.2	33.5	0.0	11.5	31	1.01
129	255	11	0	11/06	11:59:46	136.9	7.1	383.1	1.91	108	69	24.1	24.5	0.0	11.9	25	0.93
130	256	11	0	11/06	12:59:47	138.5	7.0	383.2	1.89	107	68	23.7	24.1	0.0	11.9	62	0.92
131	257	11	0	11/06	13:59:48	157.5	5.8	383.1	2.00	109	70	24.6	25.0	0.0	11.8	48	0.98
132	258	11	0	11/06	14:59:50	166.2	4.7	377.7	1.97	108	69	24.9	25.4	0.0	11.8	45	1.01
133	260	11	0	11/06	17:01:18	149.3	6.2	381.9	2.10	107	68	26.3	26.8	0.0	11.8	62	1.04

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Table 7-4. (Cont'd)

1978 1979 & 1980 RESULTS

CALCULATED FROM AVERAGED DATA SETS

row	ave	Run	Set	DATE	TIME	P1	ul	H1	kWs/kM	kWs	kW	eff%	effT2%	effPd%	P2	Thr%	eff:E/C
134	261	11	0	11/06	18:01:48	128.7	7.3	380.6	2.05	108	69	26.7	27.2	0.0	11.9	60	1.02
135	262	11	0	11/06	19:04:06	148.4	6.1	380.9	1.96	101	62	24.4	24.9	0.0	11.5	52	0.99
136	263	11	0	11/06	19:14:06	133.8	7.0	380.8	1.97	102	63	25.2	25.8	0.0	11.8	65	1.00
Low Pressure Trim: Performance Survey																	
137	269	12	73	11/11	13:23:17	188.5	3.8	380.3	3.30	563	518	41.7	41.5	42.1	12.6	36	0.95
138	272	12	0	11/11	13:25:38	182.4	4.1	380.2	3.29	564	518	40.8	39.1	41.2	12.0	38	0.94
139	275	12	74	11/11	13:39:32	113.5	8.3	379.7	3.27	556	510	46.3	45.3	48.1	13.0	98	0.96
140	278	12	0	11/11	13:41:26	112.3	8.4	379.9	3.27	552	506	45.6	45.2	47.5	12.7	99	0.75
141	281	12	75	11/11	14:05:54	185.7	15.0	474.2	5.98	550	505	42.9	43.6	44.0	11.7	29	1.02
142	6	12	76	11/11	14:23:44	104.7	16.2	444.1	5.15	530	485	50.4	50.4	52.7	12.2	100	1.05
143	9	12	0	11/11	14:41:28	179.4	23.6	545.3	8.72	543	498	48.7	48.8	50.2	12.1	29	1.14
144	12	12	77	11/11	14:51:59	189.0	26.0	568.8	8.86	553	508	45.5	45.3	46.8	12.3	27	1.07
145	22	12	79	11/11	15:12:20	103.6	29.3	559.9	8.41	538	492	53.9	53.6	56.7	12.3	100	1.12
146	27	13	80	11/13	13:16:17	162.6	14.2	457.4	5.65	803	752	46.6	45.9	47.[illegible]	12.7	72	0.99
147	30	13	0	11/13	13:16:59	163.0	13.8	454.4	5.62	803	752	47.0	42.6	48.7	12.7	71	1.00
148	33	13	81	11/13	13:20:39	149.4	14.7	455.7	5.54	836	784	47.4	46.5	49.2	12.8	100	0.98
149	36	13	0	11/13	14:17:04	155.1	14.9	459.9	5.52	728	678	42.5	37.5	42.8	10.8	65	0.94
150	39	13	82	11/13	15:13:10	144.2	30.4	589.4	9.22	847	795	49.9	47.8	51.7	13.3	100	1.02
151	47	13	83	11/13	15:14:26	144.3	30.0	585.9	[illegible].14	847	795	50.9	47.9	53.4	14.0	100	1.03
152	58	13	84	11/13	15:32:28	179.3	17.6	494.4	6.69	1059	1002	46.2	45.2	47.5	12.9	100	0.96
153	30	13	0	11/13	13:16:59	163.0	13.8	454.4	5.62	803	752	47.0	42.6	48.7	12.7	71	1.00
1980 Mexico: Endurance Testing (Continued)																	
154	40	0	21	07/28	8:41:16	185.4	23.9	551.7	8.91	907	854	54.7	54.2	0.0	15.9	56	1.12
155	41	0	22	07/28	17:01:05	183.0	22.8	541.4	8.70	910	857	55.4	54.9	0.0	15.8	59	1.13
156	42	0	23	07/28	17:02:46	183.0	22.9	542.3	8.68	909	856	55.2	54.7	0.0	15.8	59	1.13
157	43	0	24	07/28	17:55:34	183.6	22.8	541.8	8.70	911	857	55.3	54.8	0.0	15.8	59	1.13
158	44	0	25	07/28	18:47:18	186.4	22.9	543.6	8.74	910	857	55.0	54.4	0.0	15.8	56	1.13
159	45	0	26	07/28	19:39:02	187.1	22.9	544.0	8.80	914	861	55.2	54.8	0.0	15.8	56	1.13
160	46	0	27	07/28	21:01:59	189.1	23.1	546.3	8.83	913	860	54.9	54.4	0.0	15.9	54	1.13
161	47	0	28	07/28	21:20:34	189.8	23.2	546.8	8.82	910	857	54.6	54.1	0.0	15.8	54	1.12
162	48	0	29	07/29	5:05:44	188.7	23.5	549.4	8.91	911	858	54.8	54.3	0.0	15.9	54	1.13
163	49	0	30	07/29	5:46:54	180.6	22.5	537.7	8.59	911	857	55.9	55.4	0.0	15.9	60	1.14
Performance Survey																	
164	50	0	31	07/29	7:34:57	95.8	13.9	418.8	4.30	306	264	56.6	56.8	0.0	14.8	53	1.37
165	51	0	32	07/29	8:14:58	99.6	16.7	446.2	5.47	427	383	62.0	62.0	0.0	15.0	74	1.35
166	52	0	33	07/29	8:26:16	98.8	16.9	447.4	5.46	427	383	61.7	61.7	0.0	15.0	75	1.34
167	58	0	34	07/29	8:27:16	100.9	16.4	445.1	5.47	427	384	61.9	62.0	0.0	15.0	72	1.35
168	63	0	35	07/29	9:24:46	140.8	10.9	420.0	4.33	303	262	50.0	50.1	0.0	14.8	27	1.27
169	69	0	36	07/29	9:25:55	142.5	10.6	418.5	4.34	303	262	50.3	50.4	0.0	14.8	26	1.28
170	74	0	37	07/29	9:26:55	140.1	10.8	418.3	4.34	303	262	50.6	50.8	0.0	14.8	27	1.28
171	75	0	38	07/29	10:18:13	140.3	17.6	477.8	6.69	559	513	58.3	58.2	0.0	15.1	49	1.23
172	81	0	39	07/29	10:19:19	139.8	16.9	471.3	6.61	559	513	59.3	59.3	0.0	15.1	49	1.25
173	86	0	40	07/29	10:20:36	139.6	17.6	477.7	6.68	559	513	58.3	58.3	0.0	15.1	50	1.23
174	87	0	41	07/29	10:55:45	178.1	15.0	473.1	6.69	559	513	55.7	55.5	0.0	15.2	32	1.27

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Table 7-4. (Cont'd)

1978 1979 & 1980 RESULTS

CALCULATED FROM AVERAGED DATA SETS

row	ave	Run	Set	DATE	TIME	P1	Q1	H1	kWs/kW	kWs	kW	eff%	effT2%	effPd%	P2	Thr%	eff:E/C
175	95	0	42	07/29	10:56:52	180.1	15.3	476.2	6.75	559	513	55.2	55.1	0.0	15.2	31	1.21
176	98	0	43	07/29	10:57:58	179.1	15.7	478.8	6.69	560	514	54.3	54.0	0.0	15.3	32	1.19
177	6	0	72	08/15	13:44:33	140.9	25.5	546.9	8.28	698	649	55.8	55.6	0.0	15.4	71	1.14
178	9	0	73	08/15	13:45:59	142.9	25.0	543.5	8.24	697	649	55.7	55.7	0.0	15.3	68	1.14
179	12	0	74	08/15	13:47:01	140.2	25.4	545.5	8.24	697	648	55.9	55.7	0.0	15.4	72	1.14
180	13	0	75	08/15	13:52:20	141.1	25.6	547.5	8.27	697	649	55.6	55.4	0.0	15.4	71	1.13
181	14	0	76	08/15	13:54:03	140.5	25.7	547.8	8.28	697	649	55.6	55.5	0.0	15.4	71	1.13
182	15	0	77	08/15	14:22:42	176.1	27.2	576.3	9.33	910	857	53.8	53.4	0.0	16.0	67	1.09
183	21	0	78	08/15	14:24:03	175.3	27.6	579.5	9.34	910	857	53.4	53.0	0.0	16.0	69	1.08
184	26	0	79	08/15	14:25:01	174.7	27.3	576.1	9.33	910	857	54.0	53.5	0.0	16.0	68	1.09
Elevated Backpressure P2																	
185	36	0	83	00/00	0.00:00	96.4	26.3	529.6	4.49	262	219	51.2	51.0	0.0	24.8	72	1.26
186	42	0	84	08/18	12:56:13	97.5	25.7	524.9	4.43	262	219	51.1	50.8	0.0	24.8	71	1.25
187	47	0	85	08/18	12:57:22	96.8	26.1	528.2	4.48	262	219	51.1	50.9	0.0	24.7	70	1.25
188	48	0	86	08/18	13:19:12	138.4	30.5	589.1	5.88	429	384	53.1	52.9	0.0	32.2	68	1.11
189	54	0	87	08/18	13:20:16	139.2	30.4	588.2	5.88	429	384	52.6	52.8	0.0	31.8	67	1.10
190	59	0	88	08/18	13:21:21	140.5	30.3	588.1	5.89	430	384	52.9	52.8	0.0	32.1	65	1.11
191	60	0	89	08/18	13:45:05	175.3	27.5	578.1	5.59	518	471	53.1	52.8	0.0	39.8	61	1.04
192	66	0	90	08/18	13:46:00	175.3	27.5	577.9	5.61	518	471	53.1	52.9	0.0	39.6	62	1.04
193	71	0	91	08/18	13:58:56	174.9	27.4	576.8	5.58	518	471	53.4	53.0	0.0	39.9	62	1.04
4000 rpm, P2 Atmospheric																	
194	81	0	95	08/27	10:17:55	97.2	26.6	533.4	3.78	254	211	42.2	42.3	0.0	24.8	75	1.05
195	87	0	96	08/27	10:19:39	99.1	27.0	538.1	3.81	254	211	41.3	41.6	0.0	24.7	73	1.03
196	92	0	97	08/27	10:21:54	97.8	26.8	535.6	3.80	254	211	42.2	42.3	0.0	24.9	77	1.05
197	93	0	98	08/27	10:44:43	142.3	24.0	534.3	3.85	332	288	41.5	41.5	0.0	32.1	60	0.95
198	99	0	99	08/27	10:46:11	142.9	24.0	534.9	3.86	332	288	41.1	41.3	0.0	31.9	60	0.94
199	104	0	100	08/27	10:47:48	143.0	23.9	533.5	3.86	332	288	41.5	41.6	0.0	32.1	59	0.95
200	105	0	101	08/27	11:24:19	177.0	25.8	564.8	4.45	445	399	43.9	43.9	0.0	39.6	59	0.91
201	111	0	102	08/27	11:25:46	176.8	25.9	565.5	4.46	445	399	44.3	44.0	0.0	39.9	59	0.92
202	116	0	103	08/27	11:26:51	175.6	25.9	565.3	4.46	445	379	43.9	44.1	0.0	39.3	60	0.91
4000 rpm, P2 Normal																	
203	128	0	105	08/28	9:40:04	99.2	20.8	482.9	5.04	304	260	48.6	48.6	0.0	15.0	55	1.18
204	133	0	106	08/28	9:41:31	97.7	20.9	483.0	5.05	304	260	48.9	49.0	0.0	15.0	57	1.19
205	134	0	107	08/28	9:42:57	98.8	20.7	481.2	5.08	304	260	49.4	49.4	0.0	15.0	56	1.20
206	135	0	108	08/28	9:57:57	102.0	25.2	523.5	6.94	472	426	57.0	56.9	0.0	15.2	77	1.20
207	141	0	109	08/28	9:59:34	102.7	25.4	526.0	6.97	473	426	56.5	56.4	0.0	15.2	77	1.19
208	146	0	110	08/28	10:00.45	101.8	25.2	523.9	6.95	471	425	57.2	57.0	0.0	15.2	78	1.21
209	147	0	111	08/28	10:23:12	137.6	20.0	496.9	5.42	314	270	43.7	43.7	0.0	15.0	35	1.10
210	153	0	112	08/28	10:24:27	138.5	20.4	501.3	5.40	314	270	42.7	42.7	0.0	15.0	34	1.07
211	158	0	113	08/28	10:26:00	137.3	20.5	501.6	5.38	314	270	42.6	42.6	0.0	15.0	36	1.07
212	159	0	114	08/28	10:41:36	140.3	26.5	555.4	7.69	552	504	50.2	50.1	0.0	15.3	50	1.06
213	165	0	115	08/28	10:43:21	138.9	26.9	557.7	7.72	552	504	50.3	50.1	0.0	15.4	52	1.06
214	170	0	116	08/28	10:44:57	141.3	26.6	556.7	7.71	551	503	50.0	49.9	0.0	15.3	50	1.05

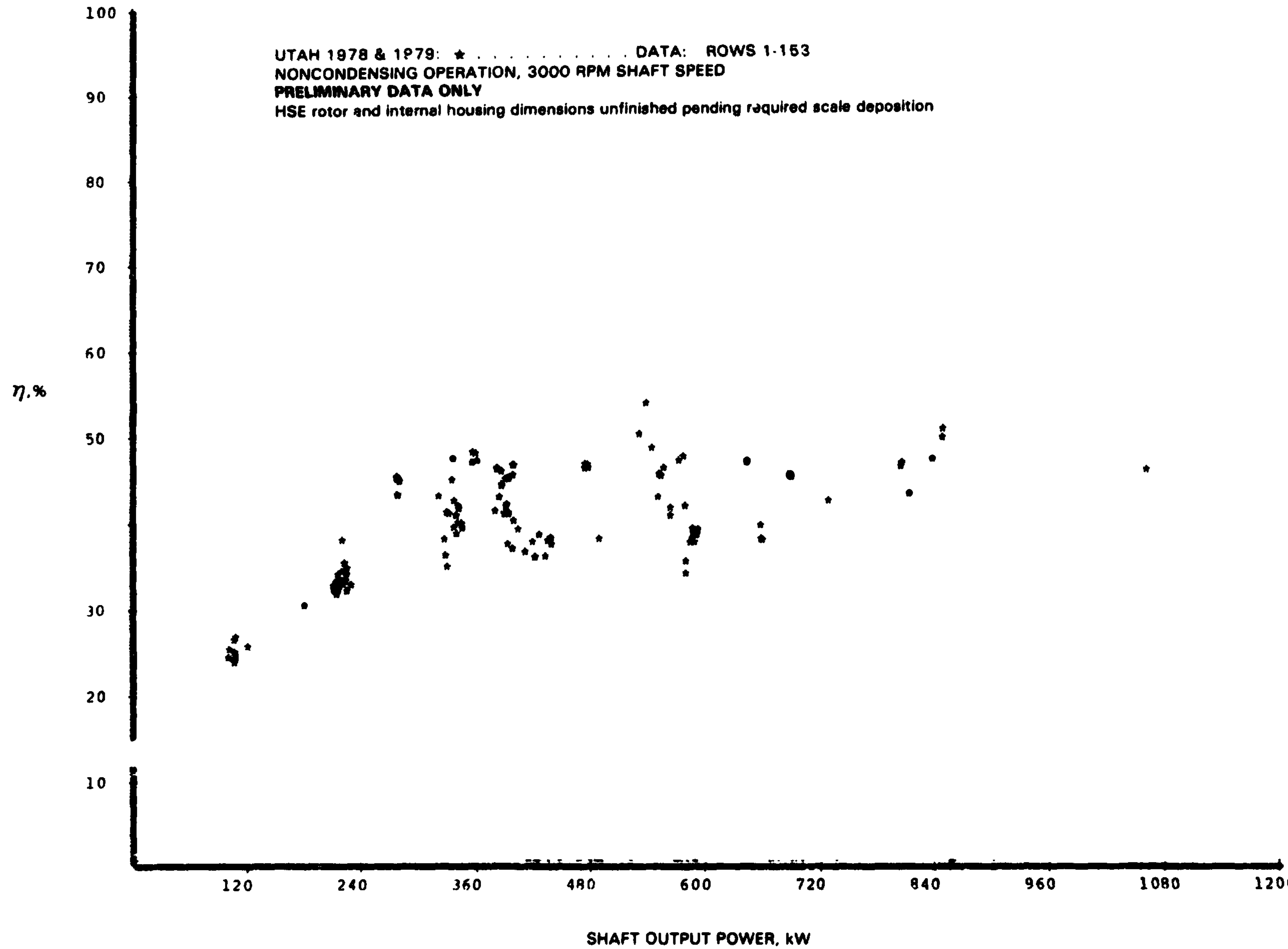

Figure 7-2. Machine Efficiency versus Shaft Output Power

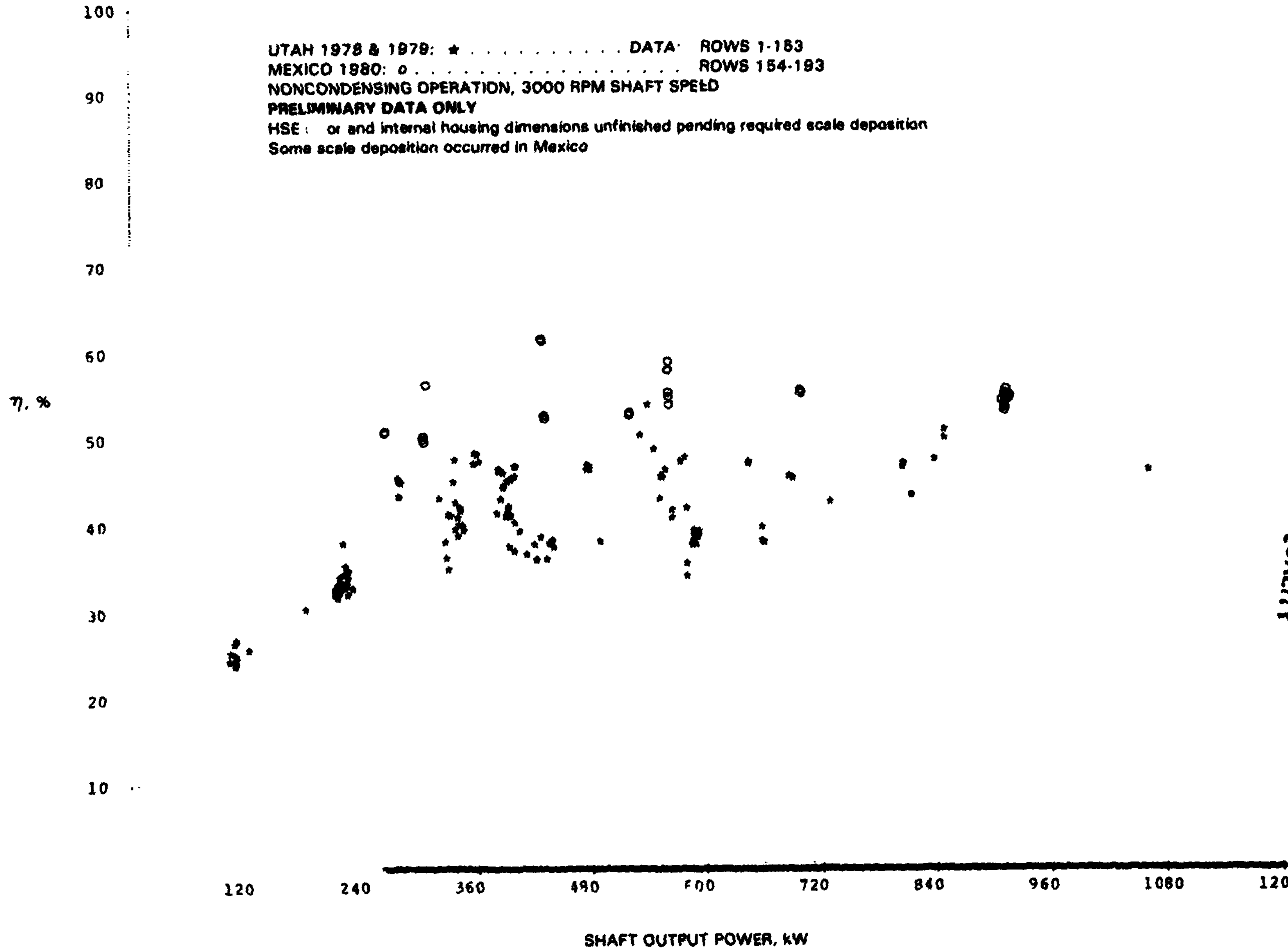

Figure 7-3. Machine Efficiency versus Shaft Output Power

to the test sites. The HSE efficiency multiplied by the ratio kW/kWs gives the approximate mechanical efficiency of the power plant. A more accurate multiplier corrects kW for all the parasitic electrical loads, and KWs for the oil pump mounted on the gear box, i.e., approximately (kW-6)/(kWs+5.6). (See Section V.B.) The power plant efficiency was not presented in this report because superimposing the gear box and alternator efficiencies on the expander efficiency tends to obscure the latter, and no effort was made to select a high efficiency gear box or alternator. The thermal efficiency was not calculated for either the HSE or the power plant because it is site-specific and part of an application analysis rather than of an expander evaluation.

2. Correlation

The Utah efficiency data were examined graphically for a means of correlation and found to be a strong function f_W of shaft output power kWs and weak functions g_P and g_Q of pressure ratio P1/P2 and inlet quality Q1, respectively. Approximate correlation equations were obtained by a trial and error procedure. First the data were plotted versus all of the different test parameters for various groups of selected data, that is, holding certain operating parameters constant. From this work it became obvious that the expander efficiency was principally a function of load. To investigate the effect of other parameters on machine efficiency, a mathematical expression for efficiency versus shaft power was necessary. A simple and convenient expression f_W which fits the data is:

$$f_W(\text{kWs}) = -21.36 + 10.25 \ln \text{kWs} - 0.072\,[\text{abs}\,(\text{kWs}-520)]^{0.6} \qquad (11)$$

Plotting the ratio of the experimental efficiency η to the efficiency f(kWs) for the various operating conditions showed that the next most important parameter affecting machine efficiency was the inlet to outlet pressure ratio P1/P2. The next most important factor was the inlet quality Q1. Consequently, it was concluded that the efficiency is approximately a function of the shaft power kWs, the pressure ratio P1/P2, and the quality Q1, that is the calculated efficiency η_C is given by:

$$\eta_C = f(\text{kWs, P1/P2, Q1}) \qquad (12)$$

In general, any function f of three variables X, Y, Z can be approximated by:

$$f(X,Y,Z) = f_X(X)\; g_Y(Y-Y_o)\; g_Z(Z-Z_o) \qquad (13)$$

where

$$f_X(X) = f(X, Y_o, Z_o) \qquad (14)$$

and g_Y and g_Z are the corrections for the less important variables, Y and Z. Consequently

$$\eta_c = f_W(kWs)\ g_Q(Q_1)\ g_P(P1/P2) \tag{15}$$

(or $f_W g_Q g_P$ as used in the data plots which follow).

If these functions are correct then the calculated efficiency η_c must equal the experimental efficiency η, or

$$\eta_c = \eta \tag{16}$$

and

$$\eta = f_W(kWs)\ g_Q(Q_1)\ g_P(P1/P2) \tag{17}$$

Therefore, solving Equation 17 yields

$$g_P = \eta/[f_W(kWs)\ g_Q(Q1)] \tag{18}$$

and

$$g_Q = \eta/[f_W(kWs)\ g_P(P1/P2)] \tag{19}$$

Thus g_P and g_Q can be obtained by finding functions g_P and g_Q that fulfill the criteria of Equations 18 and 19 as well as Equation 17 restated as Equation 20:

$$f_W = \eta/[g_Q(Q1)\ g_P(P1/P2)] \tag{20}$$

The functions g_P, g_Q and f_W normally would be found by solving Equations 6, 7, and 8 simultaneously. To find the functions was relatively easy because the effect of Q_1 and P1/P2 in Equation 20 is weak and one iteration was considered to be sufficient and the effect of Q on Equation 18 is weak and was neglected.

Based on Equation 11 for f_W,

$$g_p = 1 - 0.019\ (\frac{P1}{P2} - 15) \tag{21}$$

and

$$g_Q = 1 - 0.54\left(\frac{Q1 - 41}{100}\right)^3 + 0.0004(Q1 - 28) \qquad (22)$$

Using these values of g_P and g_Q, a better function f_W should be calculated eventually. However, further refinement of the data correlation hardly seems justified until the leakage clearances in the expander are closed and test data for a completed machine are available.

Confirmation of the correlations can be checked by plotting the ratio of experimental efficiency divided by correlation efficiency versus shaft output power (Figure 7-4) where a perfect correlation would define a line of ratio unity. This ratio η/η_C is tabulated as E/C in Table 7-4.

The correlation function f_W(kWs) (see Equation 11) has two theoretical limitations. First, at zero load the machine efficiency must be zero, and thus so must f_W(kWs) but it is not. Second, as the load climbs, a point will be reached at which the fluid leaves the expander underexpanded, and square card operation begins. At this point the expander efficiency will begin to decrease with increasing load. Nonetheless, the correlation function is valid over the range used, first because zero load data were not included in the correlation, and second, because square card operation, if any, had not become significant at the high end of the load range tested.

3. Interpretation

The correlations permit the examination and interpretation of the effects of the test variables. The effect of pressure ratio on the expander efficiency is shown graphically in Figure 7-5 where the efficiency correlated for output power and inlet quality is plotted as a function of pressure ratio. The effect of pressure ratio is defined by the slope of a line through the data which shows a decrease in the correlation ratio, and thus a decrease in efficiency as the pressure ratio increases. This effect has implications for vacuum exhaust if the correlation holds for low exhaust pressure since it implies that it is pressure ratio and not pressure which is important. Experimental data are necessary to resolve the matter. It should be pointed out that leakage past the rotors is dependent on pressure ratio, so the efficiency loss with increasing pressure ratio will diminish as the leakage diminishes.

The effect of inlet steam quality on machine efficiency can be seen in Figure 7-6 where efficiency, correlated for the efficiency function f(W) and pressure ratio function g_P, is plotted as a function of inlet steam quality. As stated above, the effects of steam quality are small.

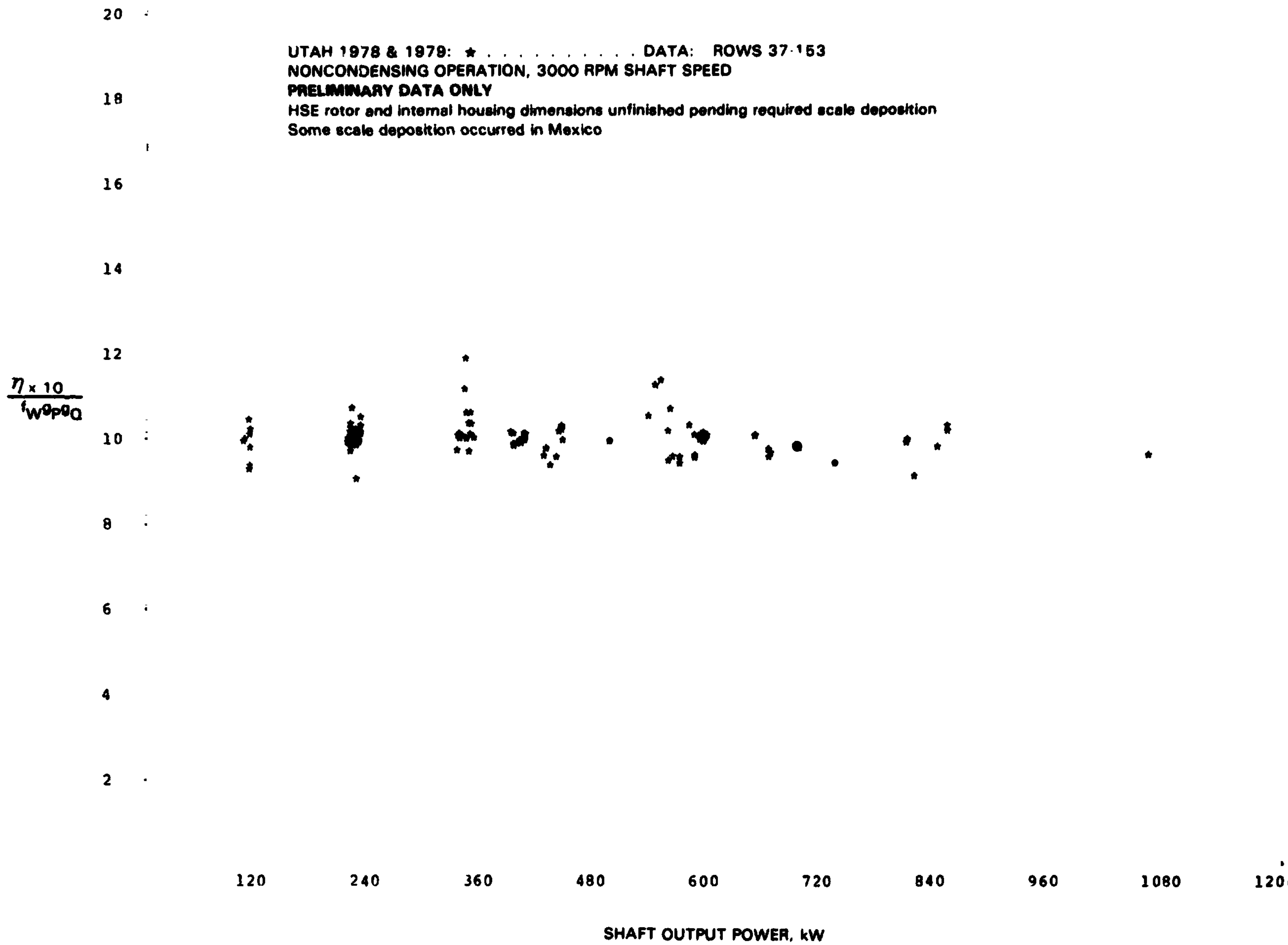

Figure 7-4. Efficiency Correlation versus Shaft Output Power

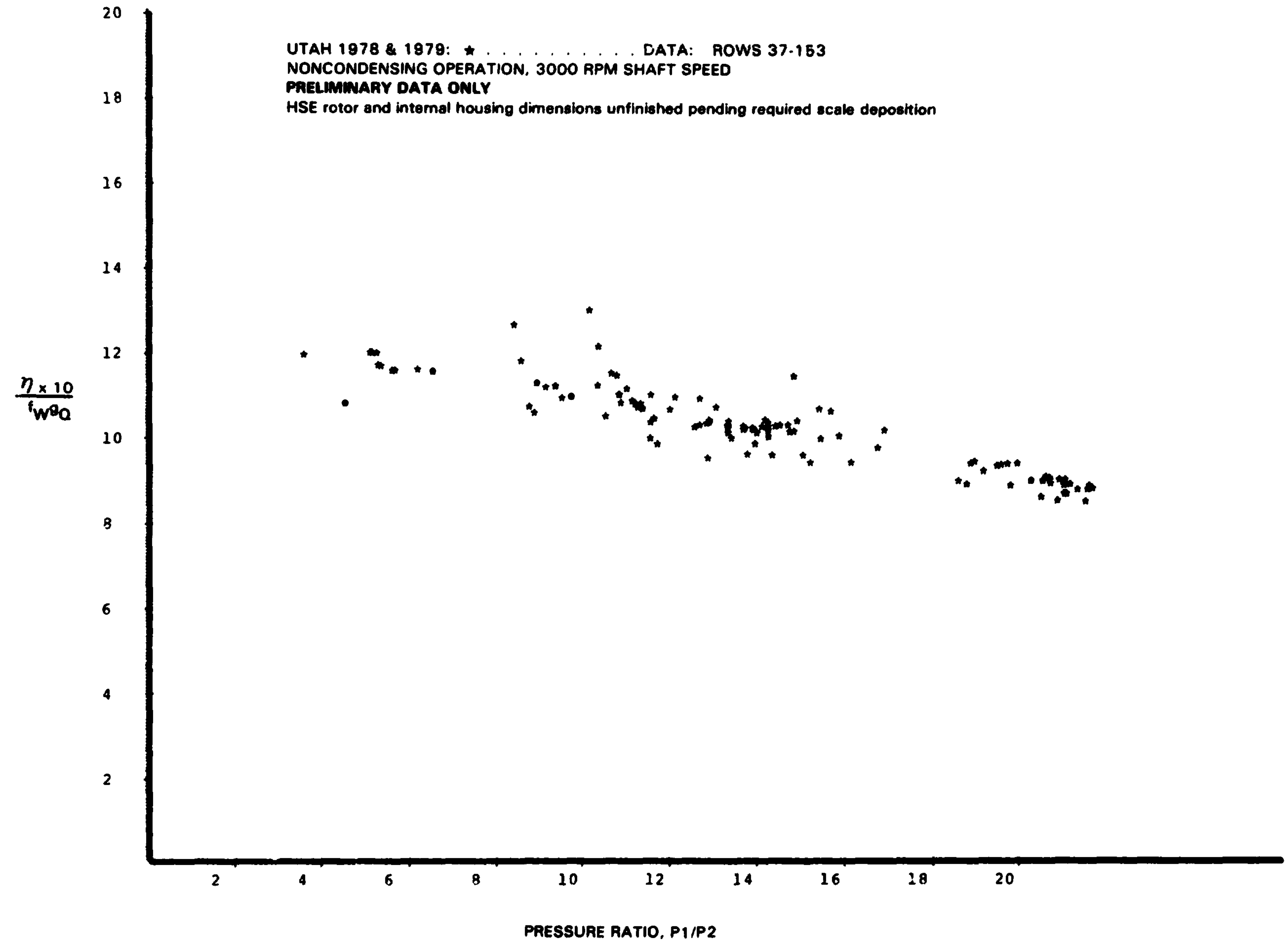

Figure 7-5. Efficiency Correlation versus Pressure Ratio

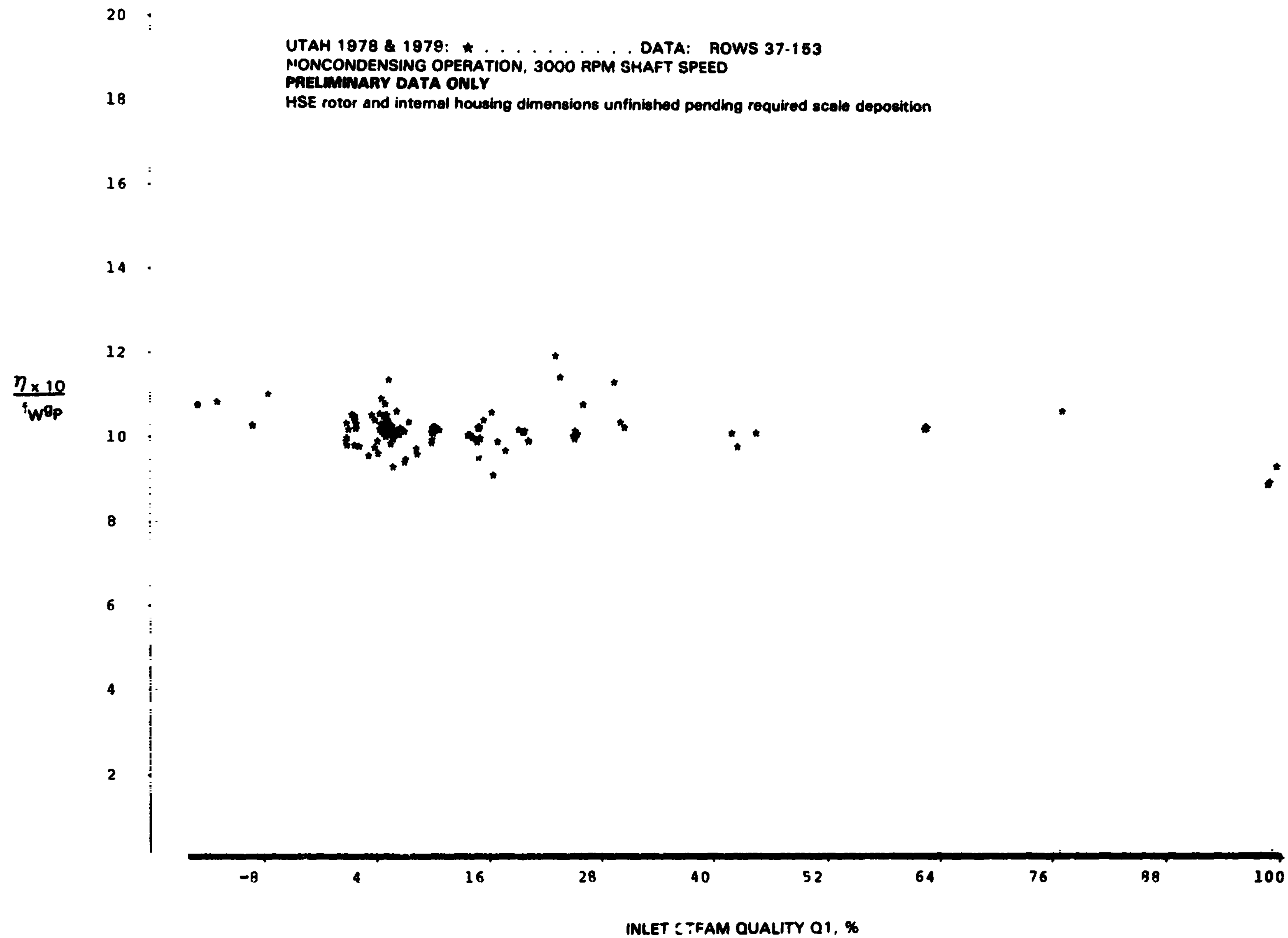

Figure 7-6. Efficiency Correlation versus Inlet Steam Quality

The importance of other test parameters on efficiency can be examined by plotting the parameter of interest versus the ratio η/η_c or $\eta/f_W g_Q g_P$. Accordingly, the effect of throttle opening is shown to be essentially nonexistent (Figure 7-7). The correlation presented in Figure 7-8 for the effects of fluid throughput M in pounds per hour shows that there is a small effect which could be included in the analysis as another weak function g_M. This should be done if more work on the performance data analysis is done.

While carrying out the above correlations, it was discovered that the correlation was somewhat better if the first thirty-six rows of Utah data were omitted. This could not be predicted by comparing Figure 7-2, in which the experimental efficiency was plotted versus shaft power for all of the Utah data, with the similar Figure 7-9, from which the first 36 rows of data were excluded. However, a difference can be seen between Figures 7-10 and 7-11, both correlated for the effects of pressure ratio and inlet quality, but with the first 36 rows of data included in Figure 7-11 and not in Figure 7-10. The slightly greater scatter in the early data may reflect some of the early difficulties with process control prior to revising the procedure for controlling the liquid level in the separator, especially prior to April 23, 1978. The omission of the first 36 rows of data from the determination of the correlation functions, as was done here, does not invalidate these data. Inspection of the results shows merely that these data exhibit more scatter, both above and below the correlated efficiency, than do the later Utah data.

Figure 7-12 is the equivalent of Figure 7-10 except that the efficiency was based on the inlet throat pressure p_D or Pd. The difference shown by a comparison of these two figures is small.

A plot of correlated efficiency duplicating Figure 7-11 (except with the 3000-rpm 1980 Mexico data included) is presented in Figure 7-13. This figure and the ratio E/C in Table 7-4 show clearly that the Mexico data do not correlate with the Utah data and that the HSE becomes a different, though similar, machine when its interior dimensions are changed by scale deposits. As the machine changes, the correlation functions must be revised. The power correlation f_W(kWs), Equation 11, will change because of better utilization of working fluid in the expansion process within the machine. The pressure ratio correlation g_P, Equation 21, will also change because the leakage past the rotors varies with pressure ratio.

C. SUMMARY OF TEST RESULTS

1. Machine Efficiency

The machine efficiency at 3000-rpm male rotor speed was demonstrated to be reasonably flat over a broad range of test conditions at shaft loads above 240 kW. A maximum efficiency of 53.9% was achieved in the Utah testing under all test conditions with the rotors and case interior substantially free of scale.

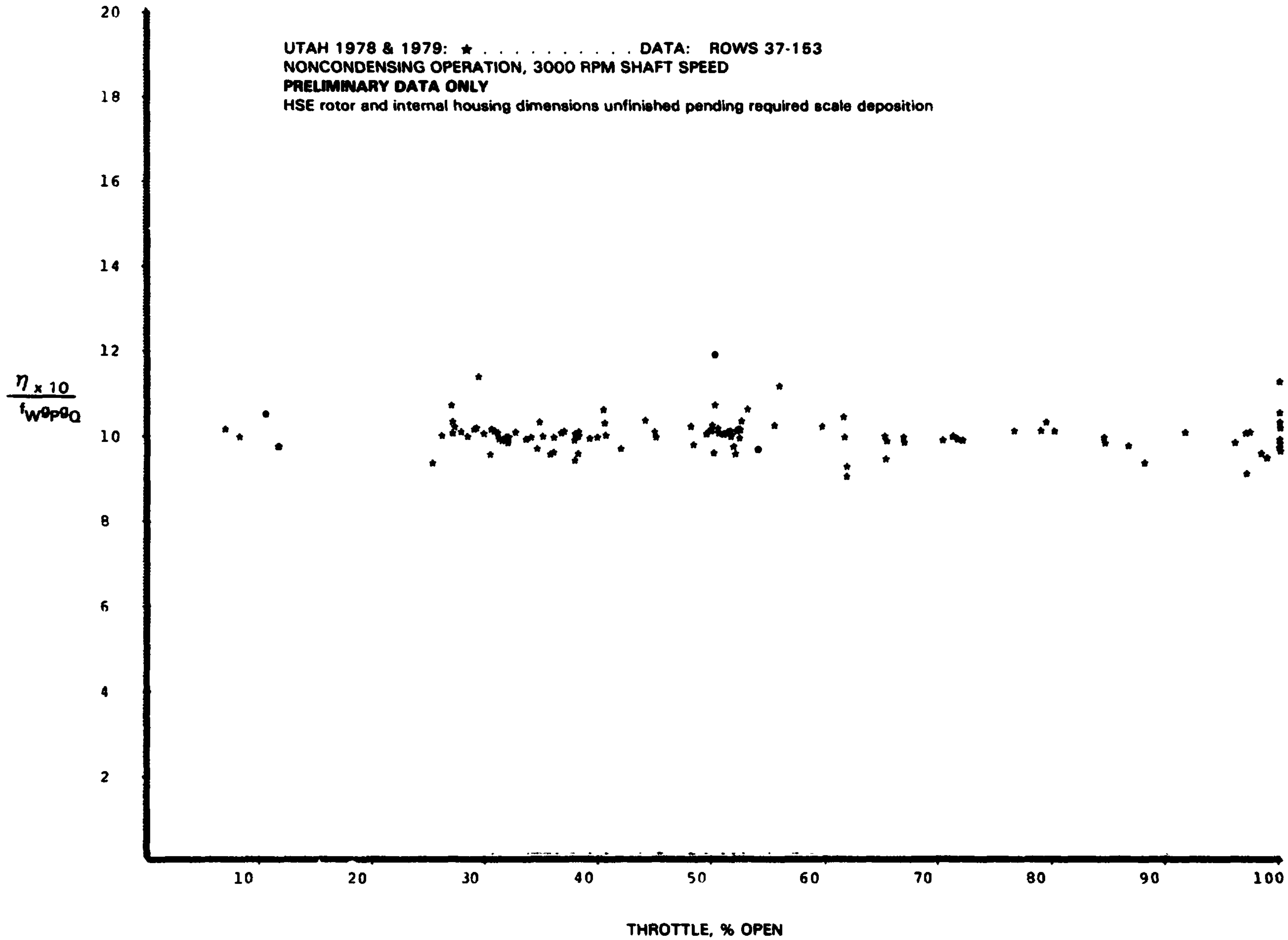

Figure 7-7. Efficiency Correlation versus Throttle Position

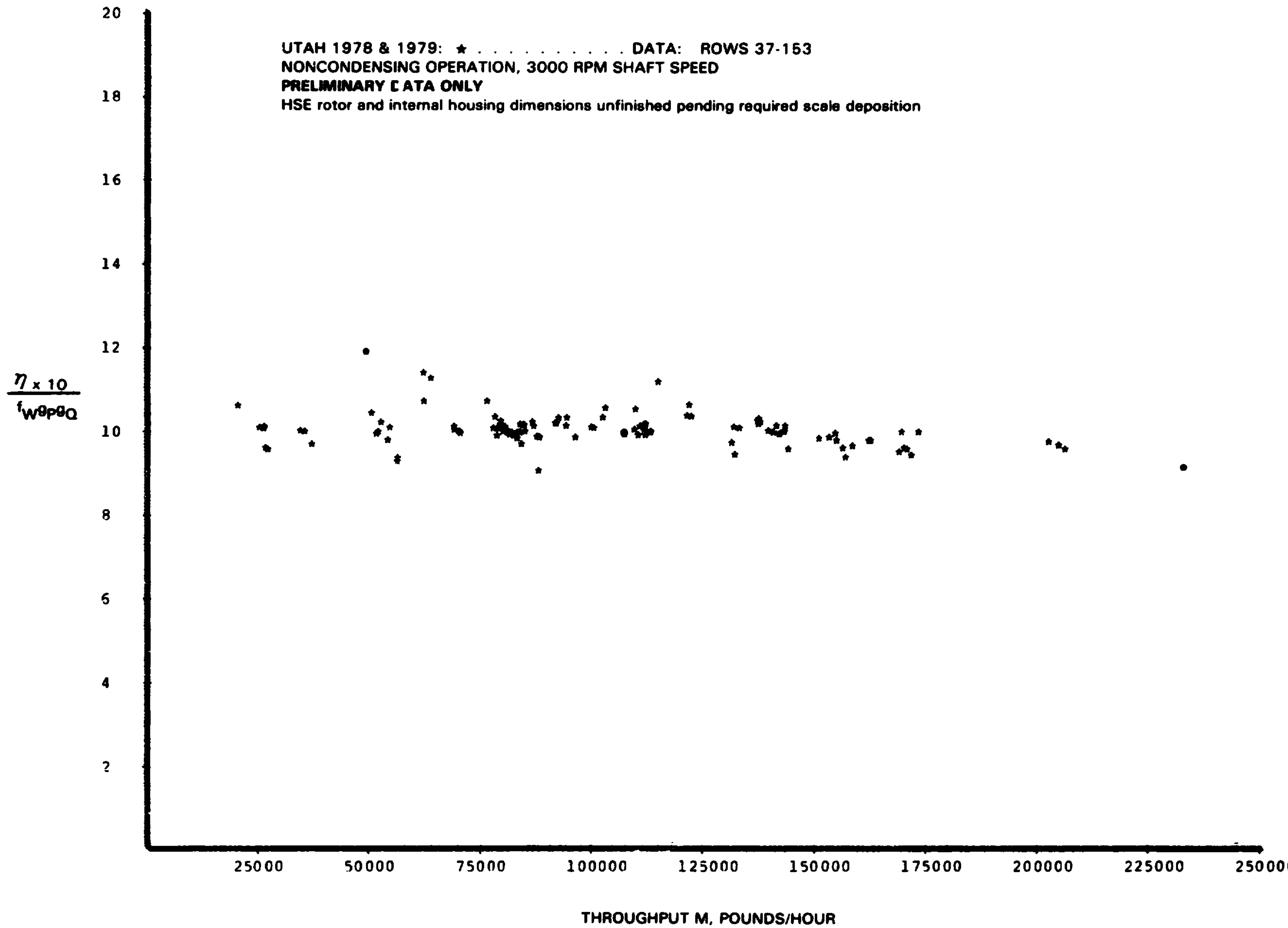

Figure 7-8. Efficiency Correlation versus Fluid Throughput

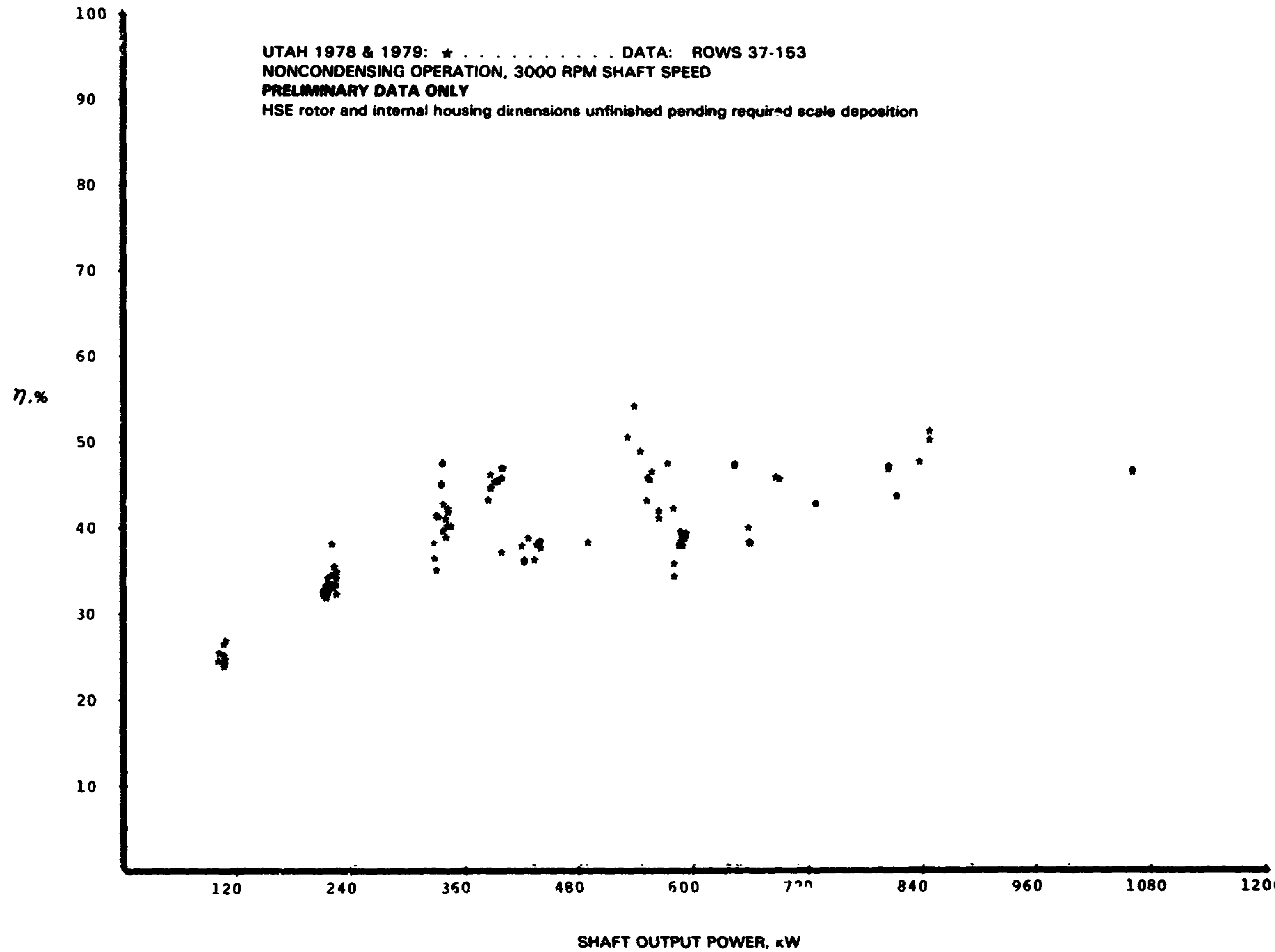

Figure 7-9. Machine Efficiency versus Shaft Output Power

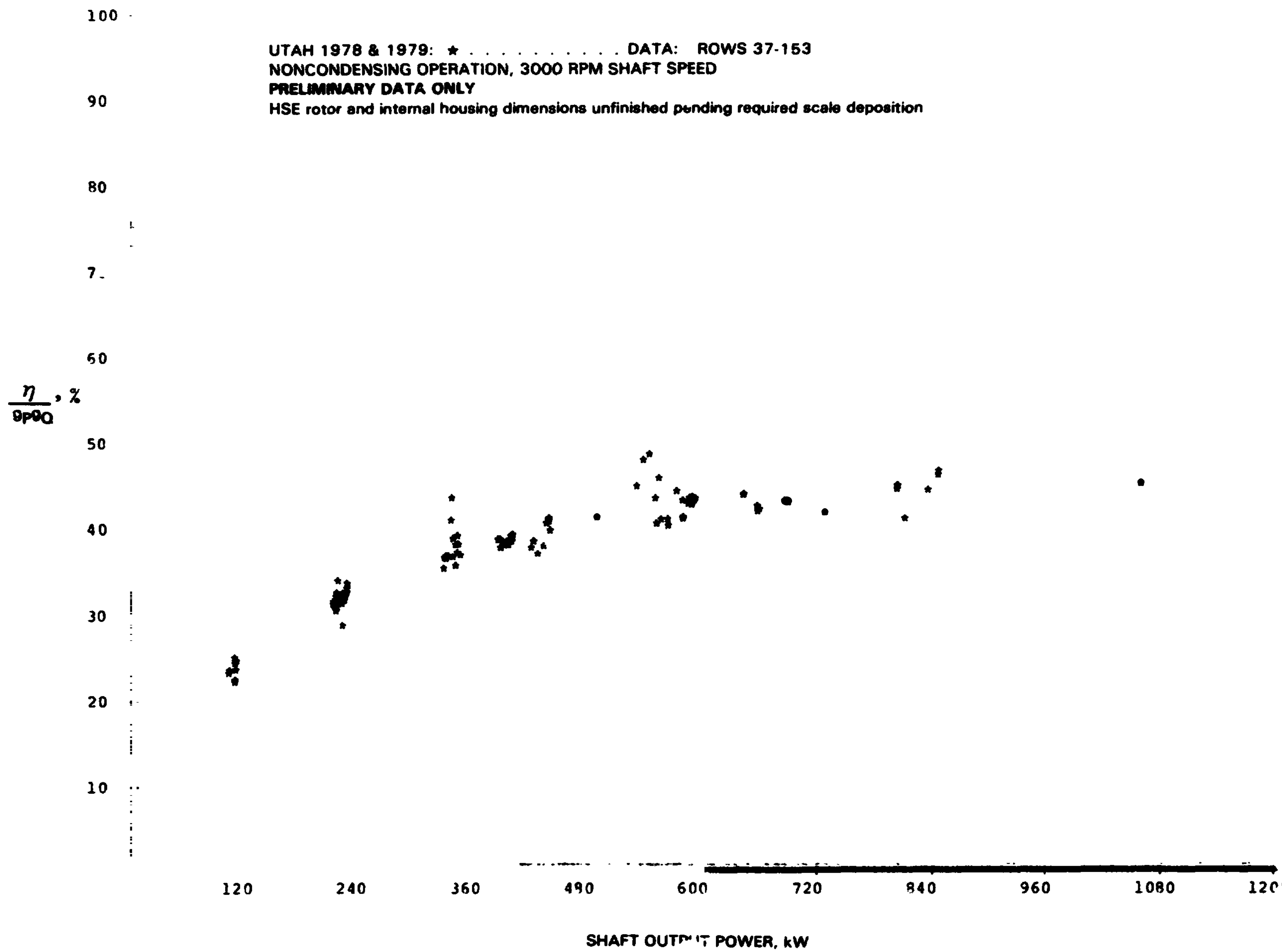

Figure 7-10. Correlated Efficiency versus Shaft Output Power

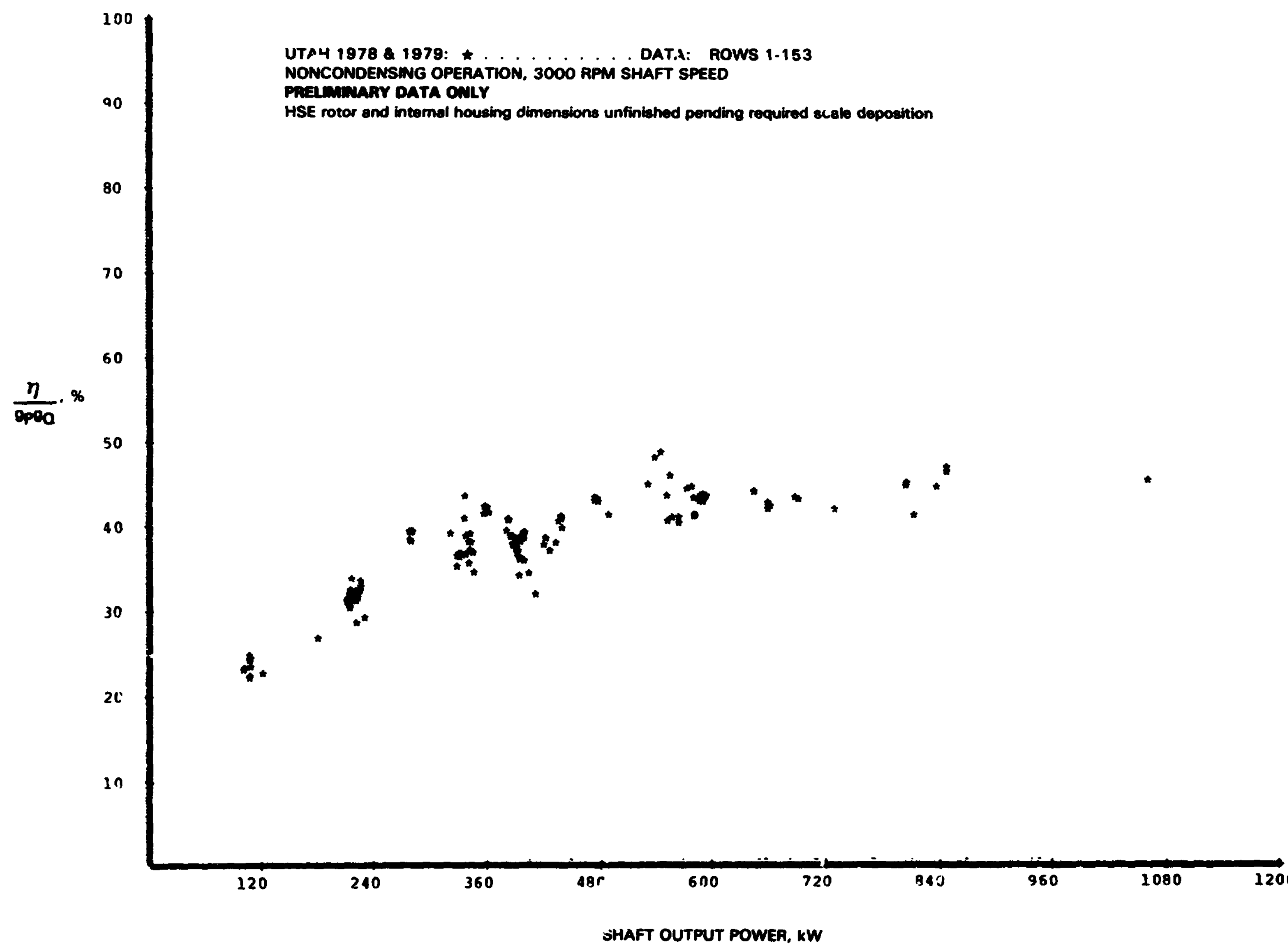

Figure 7-11. Correlated Efficiency versus Shaft Output Power

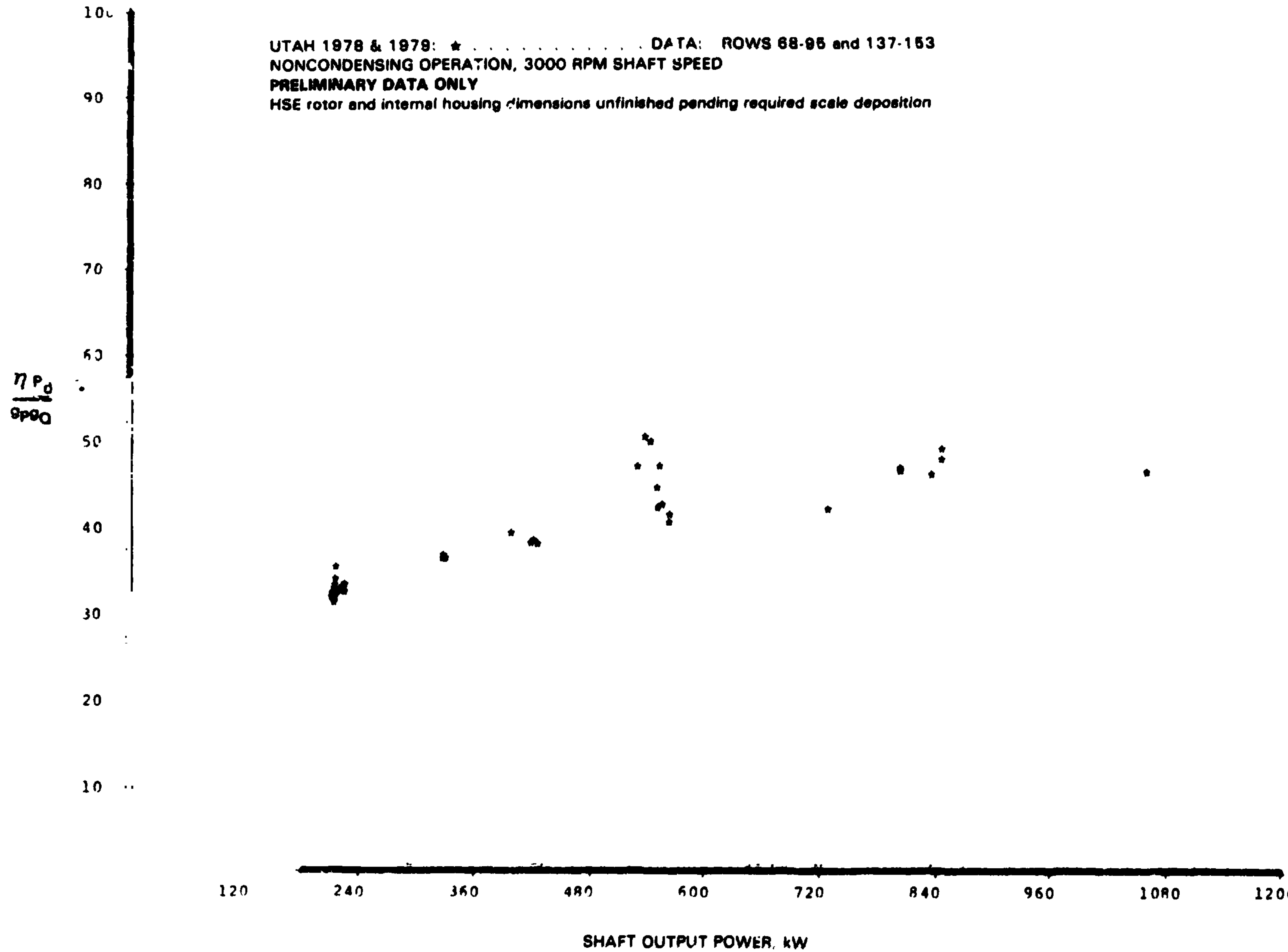

Figure 7-12. Correlated Efficiency Based on Inlet Throat Pressure versus Shaft Output Power

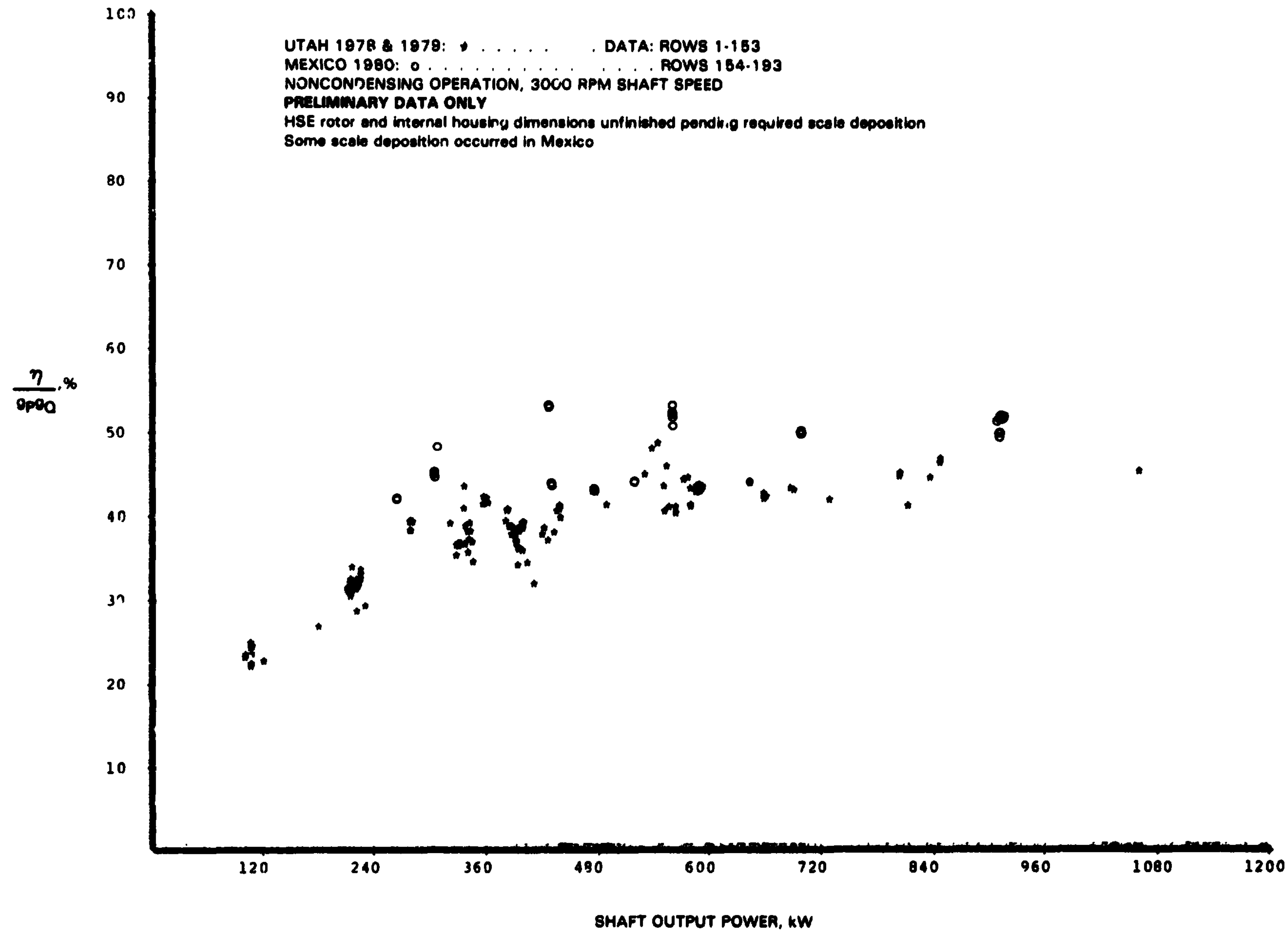

Figure 7-13. Correlated Efficiency versus Shaft Output Power

With partial scaling accomplished during the 1980 testing in Mexico, the maximum demonstrated efficiency increased to 62.0%, including 1981. The efficiency increased with increasing load, and decreased with increasing pressure ratio. The machine performance was slightly sensitive to steam fraction in the inlet fluid, and was insensitive to fluid throughput and independent of throttle position. These relationships are exhibited in Figures 7-2 and 7-4 through 7-11.

2. Operating Characteristics

The most notable characteristic was smoothness of operation of the expander and the entire drive train under all operating conditions. Starting and stopping were normally smooth and trouble-free. The effects of scale deposits within the expander, and the resulting loss of rotor clearances on the stopping and starting requirements for this machine, remain to be determined. A high noise level of 106 db exhibited by the power plant during the 1978 testing was diagnosed as coming predominately from the cooling fan in the alternator, resulting in the need for ear protection and a noise warning sign. The cooling fan was replaced with a quieter model and shrouded in preparation for the 1979 testing. The peak noise level in the hearing space near the plant was reduced, leaving the power plant still noisy but permitting removal of the noise warning sign and making ear protection optional. Success of the noise abatement efforts was graphically confirmed when two visitors chose to sit on the base of the power plant near the expander for a casual conversation during the testing in 1979.

The expander and governor were sensitive to unsteady feed conditions, either of pressure or steam fraction, especially at low load and partial throttle. A problem of instability during the first part of the 1978 tests was caused by steam in the liquid line from the separator, resulting from unsatisfactory level control. This problem was eliminated by revision of the method of level control and improvements in the feed piping such as the use of correct spool sizes and passive mixers. This is discussed in Section V.C.6. These difficulties can be considered as arising external to the expander. The expander adjusted to widely varying pressure and feed quality provided the feed was homogeneous, and the variations were not abrupt. With suitable feed, the speed regulation was typically ±0.5 Hertz or better, and varied slowly.

A water hammer within the expander inlet zone under conditions of low inlet quality and small throttle opening, observed during the 1978 tests, was totally eliminated by design improvements of the throttle valve by HPC during the machine overhaul prior to the 1979 tests.

The effects of speed and vacuum exhaust on performance were not determined.

3. Equipment Durability

A total running time of 442 hours was recorded on the elapsed time meter on the power plant during this Project. This is time during which the alternator was excited. The first 5 hours resulted from testing on air in 1977 prior to going to the field. The next 337 hours were logged in the 1978 testing in Utah, of which 182 were non-stop, and the remaining 100 hours were logged during the 1979 testing in Utah. The results of the more prolonged testing in Mexico, bringing the total operating time to 1,543 hours, are not discussed here.

Equipment failures occurred in the governor system and in the shaft seals, both during the pre-delivery testing on air in 1977 and during the fluid testing in 1978. Minor but persistent functional failures occured in the hydraulic system associated with the safety shutdown of the power plant.

a. Governor Failures. The governor failures resulted from inadequate compliance in the coupling of the governor to the expander rotor shaft which drives it. Initially, allowance was not made for the radial motion of the rotor shaft in its large bearings as compared with the small governor shaft and bearings. The failure in the field occurred within the first few minutes of testing and was attributed to dimensional changes of the expander housing caused by thermal expansion because of the hot geothermal fluids. The second repair solved the problem.

b. Shaft Seal Failures. The shaft seals were initially oil-backed, segmented carbon assemblies with hardened sleeves over the rotor shafts. Two failures occurred during the accepted testing on air in 1977 and were attributed to excessive heating by redundant seals, and to inadequate clearances between the sleeves and the seal retainers. The inadequate clearances were increased to allow for thermal expansion of the sleeves, and some of the seal assemblies were omitted to reduce the heating with good results. During field testing in 1978, two additional problems occurred. First, pulsating pressure on the seal assemblies from the geothermal fluids unseated the carbon segments. Dirt or scale evidently got under some of the sealing faces and allowed excessive leakage of the oil. Twice, the sleeve at the low pressure end of the male rotor cracked. The cracks allowed excessive leakage of oil past the seals and into the rotor area. Operation was continued by introducing air as a buffer into the seal assemblies at the high pressure end of the machine to alleviate the leakage. The second such sleeve failure occurred early May 30, 1978, terminating the test run one day before the scheduled shutdown of the well. The failure was analyzed, but the exact failure mode was not determined. As part of the repair and overhaul of the expander in preparation for the 1979 testing, the shaft seals and seal assemblies were redesigned. No subsequent seal difficulties were experienced.

c. Hydraulic System Failure. The hydraulic system associated with the safety shutdown of the power plant includes two pilot-operated solenoid valves connected to a hydraulic/pneumatic actuator on a gate valve. On numerous occasions at all test sites the solenoid valves failed to close, preventing the arming of the shutdown system and the starting of the plant. The problem in most cases resulted from dirt in the system.

D. CONCLUSIONS

This report presents very reliable data of the testing of an unfinished HSE having internal clearances which permitted serious leakage past the rotors. The average efficiency of the machine, as tested in this Project, was approximately 45%, whereas efficiencies as high as 62% were subsequently demonstrated by the machine when scale deposits within the machine partly filled the leakage clearances. The Project objectives of measuring the performance characteristics and the efficiency attainable by the HSE were not determined and will not be determined until scale deposits, or some other means such as fabricaiton changes, close the clearances. Other conclusions are listed below:

(1) The effects of drag on the starting and stopping characteristics of the machine and on efficiency which will ultimately result from scale deposits within the machine have not been determined. Unless the drag losses are known, the prediction of efficiency gain due to the closing of leakage clearances is speculative. If the drag losses are small it is conceivable that the efficiency might reach or exceed 70% under certain operating conditions.

(2) The optimum speed of the rotors has not been determined for any operating condition.

(3) The tolerance of the HSE expander to geothermal brines, and the insensitivity of the machine efficiency to steam fraction in the feed, imply the feasibility of its broad application in liquid-dominated geothermal field service, including application to pumped non-flashing wells or to waste liquid from separators.

(4) The dependence of machine efficiency on pressure ratio for exhaust pressures over the range 11.4 psia to 33.2 psia, shown in Figure 7-5, supports the hypothesis that the normal benefits of expansion to vacuum can be realized for this machine at exhaust pressures well below 11.4 psia. This must be examined experimentally. As the clearances within the machine are reduced, the dependence of efficiency on pressure ratio can be expected to decrease, thus strengthening the case for condensing operation.

(5) The design improvements and repairs made to the HSE power plant in the course of this Project were successful. The need remains for additional improvement in the governor control system to accommodate the

sudden loss of a large load, or of small loads at high feed pressure and rapidly changing feed conditions.

(6) Many more hours of operation will be required before the durability of the machine is known. Results to date are favorable.

(7) The automatic safety shutdown system affords the power plant good protection against the faults which are monitored.

(8) The 1-MW size of the power plant increased the cost and formidability of this Project vis-a-vis a smaller power plant, but provided the desired test credibility which might have been lacking otherwise.

(9) The design, development and use of a computer-controlled on-line data system greatly enhanced the versatility and yield of the test program and met or exceeded all of the test design goals.

(10) The test array approach, featuring a test system which could be easily moved and reassembled in a functionally reproducible arrangement, proved to be very satisfactory.

E. RECOMMENDATIONS

The following recommendations are made by JPL:

(1) The efficiency of the HSE should be measured, and the performance characterized under scale-forming conditions with the rotors and case interior coated with scale to their finished dimensions.

(2) Under the conditions of (1) above, the effects of speed on the efficiency and performance characteristics of the HSE should be measured. (A few preliminary tests at 4000-rpm male rotor speed, but without the finished expander dimensions, were conducted by CFE in Mexico in 1980, but the results are not discussed in this report.)

(3) Under the conditions of (1) above, the effects on the efficiency and performance characteristics of the HSE should be measured, especially including vacuum exhaust. (A few preliminary tests at reduced back pressure, but without finished expander dimensions, were conducted by CFE in Mexico in 1981, but the results are not discussed in this report.)

(4) Many hours should be logged, under the conditions of (1) above, to determine the endurance of the HSE in general and the wear characteristics of the scale-abrading surfaces.

(5) A jacking motor should be installed on the HSE to turn the rotors slowly during warm-up and cool-down to avoid rotor contact caused by thermal distribution and to avoid seizing of the rotors due to scale during start-up or shutdown of the power plant. (The necessary equipment was installed in Mexico.)

(6) A centrifugal water/oil separator should be installed in the oil return line from the shaft seal assemblies to remove flush water from the recirculating oil. (The necessary equipment and was installed in Mexico.)

(7) A multistage centrifugal pump should be installed in the flush water supply to the shaft seals to replace the four piston-type metering pumps which were used with the new seal assemblies in 1979. Pulsation from the metering pumps tended to unseat the seals despite pulse dampers installed between the pumps and seals. (The necessary equipment was installed in Mexico.)

(8) All carbon steel parts in the shaft seal flush water system should be replaced with stainless steel.

(9) The hydraulic system for the automatic stop valve should be cleaned to stop a series of minor problems which have been caused by dirt.

(10) The 24-Volt electrical system for fault protection of the HSE power plant should be isolated in its own enclosure as much as possible.

(11) The next HSE power plant should have its own fault recorder to show first fault.

(12) The next HSE power plant should have removable wheels, axles, and other accessories for the main base to permit towing it from place to place without the need of a crane or flatbed truck.

The following recommendations were by HPC (Ref. 5):

(13) The next HSE power plant should be assembled on a longer and wider base for easier equipment access for servicing and maintenance.

(14) The supply pipe to the HSE should be welded to the base, rather than bolted, to better protect the alignment of the HSE from movement of the supply pipe from the field.

(15) The hydraulic/pneumatic actuator on the automatic stop valve should be positioned vertically to prevent the loss of compressed nitrogen past the piston.

(16) The hyraulic/pneumatic actuator on the automatic stop valve should have an adjustable stroke cushion to reduce mechanical stresses on the main drive train during fault shutdown.

(17) An electric pump should replace the hand pump for plant start-up.

(18) Additional inspection ports should be built into the prime mover housing for rotor inspection.

(19) Improvements should be made to the governor control system to provide stable plant operation for unstable inlet pressures, steam fraction or electrical load.

(20) Provision for additional cooling capacity should be incorporated into the lube oil console for use in hot desert environments.

(21) The capacity of the lube oil reservoir should be increased to accommodate prolonged loss due to nominal shaft seal leakage.

(22) A hydrogen sulfide removal system should be installed in all electrical enclosures.

SECTION VIII

IEA PROGRAMME PLANNING SUPPORT

The DOE/DGE, as a member of the IEA, agreed to participate in a program of research, development and demonstration on geothermal equipment. The decision by DOE/DGE in the spring of 1978 to terminate this project carried with it the obligation to offer to other member countries the opportunity to test the HSE. The offer was promptly accepted by member and non-member countries. An implementing agreement was then signed by DOE/DGE for the United States, CFE for non-member Mexico, ENEL for Italy and MWD for New Zealand. Terminaton of this project was delayed in order to overhaul the HSE to correct the shaft seal failure and to confirm the adequacy of the overhaul so that the IEA Test Programme could proceed.

During the period of overhaul and test activities in Utah, this Project provided planning support for the IEA Programme. This support included conducting test demonstrations and training sessions in Utah, attending planning meetings with Programme participants in Washington, D.C., and assisting CFE with planning for the testing at Cerro Prieto, Mexico. Test process literature was prepared by JPL for distribution by DOE/DGE to other participants, and JPL prepared and distributed a series of planning and descriptive memoranda.

Representatives of Mexico, Italy, New Zealand, Turkey, Sweden and Germany attended the test demonstrations, and staff members of CFE attended the training sessions. The major part of the planning support was for the testing in Mexico, because testing was to take place there first. This support included copies of computer programs undergoing development in Utah, preparation of process designs compatible with CFE test objectives, process equipment lists, and an analysis and recommendations concerning the use of candidate wells.

CFE proposed using either Well M-11 or M-114 and submitted the production characteristics to JPL for review. The data for Well M-11 are presented in Table 8-1 and graphically in Figure 8-1; data for Well M-114 are presented in Table 8-2. CFE desired to use M-11 because it was old and known to be stable. It had a total production of about 51 tons per hour, versus 257 tons per hour for M-114, and therefore it was less important to the main power plants.

For the operating points of Tables 8-1 and 8-2, the shaft output power was calculated for an expander assumed to have 50% efficiency and an adequate size for four assumed modes of operation, namely, using the total production, or using the water only, for exhaust pressures of 14.7 psia and 3.0 psia. The calculated results and other relevant data were added to these tables in the blank spaces, with the operating points keyed to the original data by row number (Tables 8-1a and 8-2a). These results show that Well M-114 can produce 1 MW for all operating points, but that Well M-11 cannot. However, the output power was considered to

Table 8-1. Production Characteristics of Well M-11, January 9, 1979 (Courtesy of CFE)

COORDINADORA EJECUTIVA DE CERRO PRIETO B. C.
COMISION FEDERAL DE ELECTRICIDAD
SUPERINTENDENCIA MANTENIMIENTO Y OPERACION POZOS

PRODUCCION DE VAPOR Y AGUA DE POZOS EN OPERACION

Pozo	Fecha de Medicion	Nivel Agua Separador	Presion Pozo, psig	Presion Separador psig	Produccion Separador, ton/h			Relacion, Agua/Vapor	Entalpia, kcal/kg	Temperatura, C
					Vapor	Agua	Mezcla			
M-11	9 Enero'79	Si	90.5	90.5	14.95	36 35	51.30	2.43	311.55	293.0
M-11	9 Enero'79	Si	166.0	90.0	14.51	36.84	51.35	2.54	307.03	289.0
M-11	9 Enero'79	Si	266.0	89.8	13.81	35.82	49.63	2.59	304.89	287.0
M-11	9 Enero'79	Si	385.0	90.0	12.45	33.32	45.77	2.68	301.83	285.0
M-11	9 Enero'79	Si	494.0	89.0	10.77	28.01	38.78	2.60	304.46	287.0
M-11	9 Enero'79	Si	576.0	87.8	7.99	23.01	31.00	2.88	294.15	279.0
M-11	9 Enero'79	Si	589.0							

Table 8-1a. Production Data and Utilization Options for Well M-11

COORDINADORA EJECUTIVA DE CERRO PRIETO B. C.
COMISION FEDERAL DE ELECTRICIDAD
SUPERINTENDENCIA MANTENIMIENTO Y OPERACION POZOS

PRODUCCION DE VAPOR Y AGUA DE POZOS EN OPERACION

No.	Pozo	Fecha de Medicion	Nivel Agua Separador	Presion Pozo, psig	Presion separador, psig	Produccion Separador, ton/h			Relacion, Agua/Vapor	Entalpia, kcal/kg	Temperatura, C
						Vapor	Agua	Mezcla			
1	M-11	9 Enero'79	Si	90.5	90.5	14 95	36.35	51 30	2.43	311.55	293.0
2	M-11	9 Enero'79	Si	166 0	90.0	14.51	36.84	51.35	2.54	307.03	289.0
3	M-11	9 Enero'79	Si	266.0	89 8	13.81	35.82	49.63	2.59	304.89	287.0
4	M-11	9 Enero'79	Si	385.0	90.0	12 45	33 32	45 77	2 68	301 83	285.0
5	M-11	9 Enero'79	Si	494.0	89 0	10.77	28.01	38.78	2.60	304.46	287.0
6	M-11	9 Enero'79	Si	576.0	87.8	7.99	23.01	31.00	2.88	294.15	279.0
7	M-11	9 Enero'79	Si	589.0							

No	Wellhead Pressure	Enthalpy, h	h_f	h_{fg}	Wellhead Steam Quality,	Mixed Flow Power[a] @ 1-atm Exhaust	Mixed Flow Power[a] @ 3-psia Exhaust	Liquid Flow Rate m_f	Liq. Only Power[a] @ 1-atm Exhaust	Liq. Only Power[a] @ 3-psia Exhaust	Separator Production Quality,
	psia	Btu/lb	Btu/lb	Btu/lb		kW	kW	ton/h	kW	kW	
1	105.2	520.79	302.24	385.88	29.2	812.3	1452.5	36 32	117.9	301.0	29.2
2	180.7	552 65	346.37	850.52	24.25	957.8	1569.0	38.90	224 8	468.8	28.3
3	280 7	548.86	387.22	815.08	19.83	1020.6	1595.0	39.79	344.0	636.7	27.3
4	399.7	543 29	424.0	780 5	15.28	914.7	1501.2	38 78	451 2	772.3	27.2
5	508.7	548.03	451.44	752.87	12 83	880 4	1219.4	33.80	476.3	779.1	27.8
6	590 7	529.47	469.65	733.7	8 15	663 1	998.8	28.47	450.6	717.9	25.8
7	603 7										

Note. $h = h_f + xh_{fg}$.

[a] Assumes 50 expander efficiency.

Table 8-2. Production Characteristics of Well M-114, January 20-22, 1978 (Courtesy of CFE)

COMISION FEDERAL DE ELECTRICIDAD
COORDINADORA EJECUTIVA DE CERRO PRIETO
SUPERINTENDENCIA DE PRODUCCION
REPORTE DE PRODUCCION DE AGUA Y VAPOR CON PRESION CRITICA Y VERTEDOR
POZO M-114

Fecha	Presion Cabezal, kg/cm^2	-in. Tuberia Descarga	-in Orificio	Entalpia kcal/kg	Gasto Masa, ton/h	Vapor @ 7.03 kg/cm^2 ton/h	Agua @ 7.03 kg/cm^2 ton/h
20-XI-78	32.55	8	2	291.67	89.06	21.80	67.26
21-XI-78	31.99	8	2	295.33	88.11	22.32	65.79
21-XI-78	28.61	8	3	273.61	152.61	31.73	120.88
21-XI-78	22.64	8	4	265.28	215.87	41.21	174.66
22-XI-78	22.29	8	4	272.22	206.99	42.45	164.54
22-XI-78	17.36	8	5	273.61	240.80	50.06	190.73
22-XI-78	16.87	8	5	272.22	241.23	49.47	191.76
22-XI-78	13.71	8	6	275.00	254.04	53.54	200.50
22-XI-78	13.71	8	6	275.00	254.04	54.12	202.68

Table 8-2a. Production Data and Utilization for Well M-114

COMISION FEDERAL DE ELECTRICIDAD
COORINADORA EJECUTIVA DE CERRO PRIETO
SUPERINTENDENCIA DE PRODUCCION
REPORTE DE PRODUCCION DE AGUA Y VAPOR CON PRESION CRITICA Y VERTEDOR
POZO M-114

No.	Fecha	Presion Cabezal, kg/cm²	-in. Tuberia Descarga	-in. Orificio	Entalpia, kcal/kg	Gasto Masa, ton/h	kW	Vapor @ 7.03 kg/cm² 99.78 psig 114.48 psia ton/h Quality, %		Agua @ 7.03 kg/cm² ton/h
1	20-XI-78	32.55	8	2	291.67	89 06	1297	21.48	21.80	67.26
2	21-XI-78	31.99	8	2	295.83	88.11			22.32	65.79
3	21-XI-78	28.61	8	3	273.61	152 61			31.73	120.88
4	21-XI-78	22.64	8	4	265 28	215 87			41.21	174.66
5	22-XI-78	22.29	8	4	272 22	206.99			42.45	164 54
6	22-XI-78	17.36	8	5	273.61	240.80			50.06	190.73
7	22-XI-78	16 87	8	5	272.22	241.23			49.47	191.76
8	22-XI-78	13.71	8	6	275.00	254.04	3307	21.08	53.54	200 50
9	22-XI-78	13.71	8	6	275.00	256 70	3327	21.30	54.12	202

No	Wellhead Pressure psig	Wellhead Pressure psia	Enthalpy, Btu/lb	Wellhead Quality,	Mixed Flow Power, kW[a] 1-atm Exhaust	Mixed Flow Power, kW[a] 3.0-psia Exhaust	Agua Flow Rate, ton/h	Liquid Only Power, kW[a] 1-atm Exhaust	Liquid Only Power, kW[a] 3.0-psia Exhaust
1	463.0	477.7	525.01	10.65	1825	3068	79 58	1066.9	1764.9
3	406.9	421 6	492.50	8.09	2658	4186	140.26	1702.9	2886.6
4	322.0	336.7	477.50	9.00	3394	5483	196.4	1983.0	3521 6
6	246.9	261.6	492 50	13.66	3901	5337	207.91	1690.3	3183.0
8	195.0	209.7	495.00	16 13	3969	6578	213.06	1417.8	2830 5

[a]Assumes 50 expander efficiency

be adequate for two-phase, noncondensing testing to justify using the smaller well. Moreover, this well was closer to a lagoon which represented a possible source of cooling water for the condensing operation. It was found that the computer program used in these calculations produced a small error in the results, but the results were adequate for design purposes. Moreover, the production of Well M-11 was measured again and was found to have changed somewhat.

The calculated results from Table 8-1a were plotted in Figure 8-1, and are presented in Figure 8-1a as Test Opportunity Curves. For this purpose, shaft output power in units of 100 kW and steam quality in % have been added to the ordinate. The vapor, liquid and combined flow rates for the original data points and for the points in Figure 8-1a which are of interest in condensing testing have been added for presentation in Figure 8-1b. These curves and data helped to guide the process designs and the test operations at Cerro Prieto.

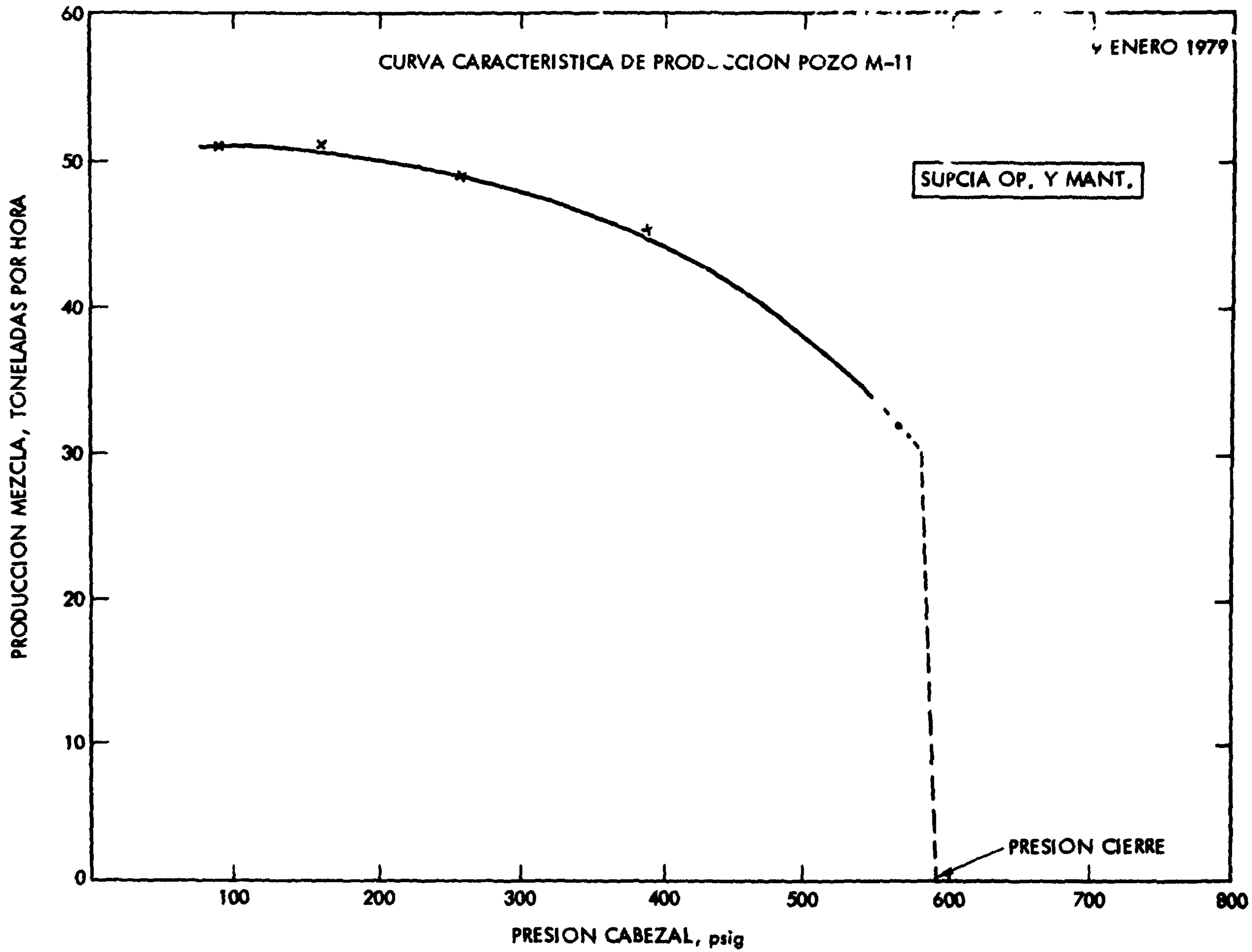

Figure 8-1. Production Characteristics of Well M-11 (Courtesy of CFE)

C-3

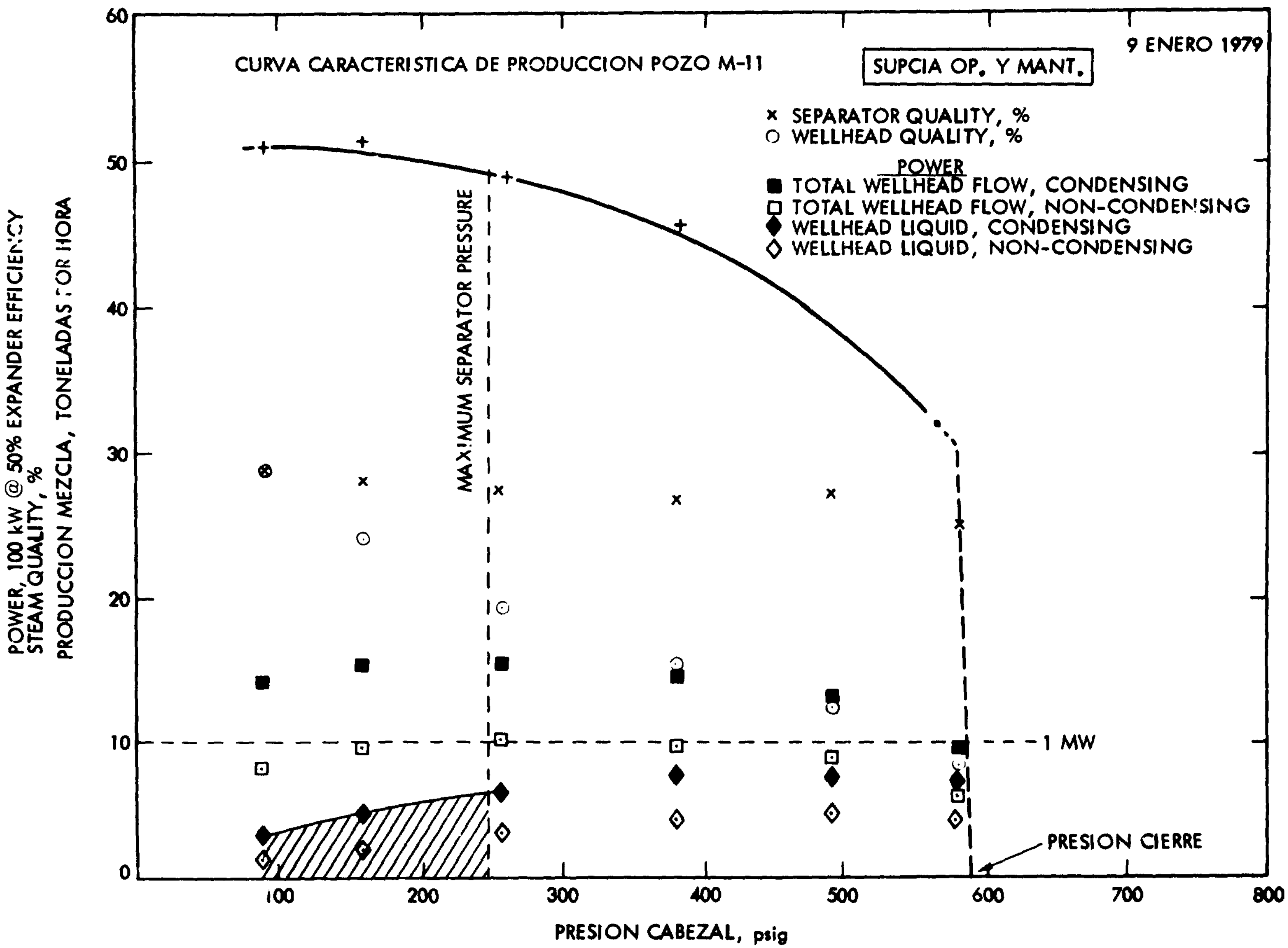

Figure 8-1a. Production and Test Opportunity Curves for Well M-11

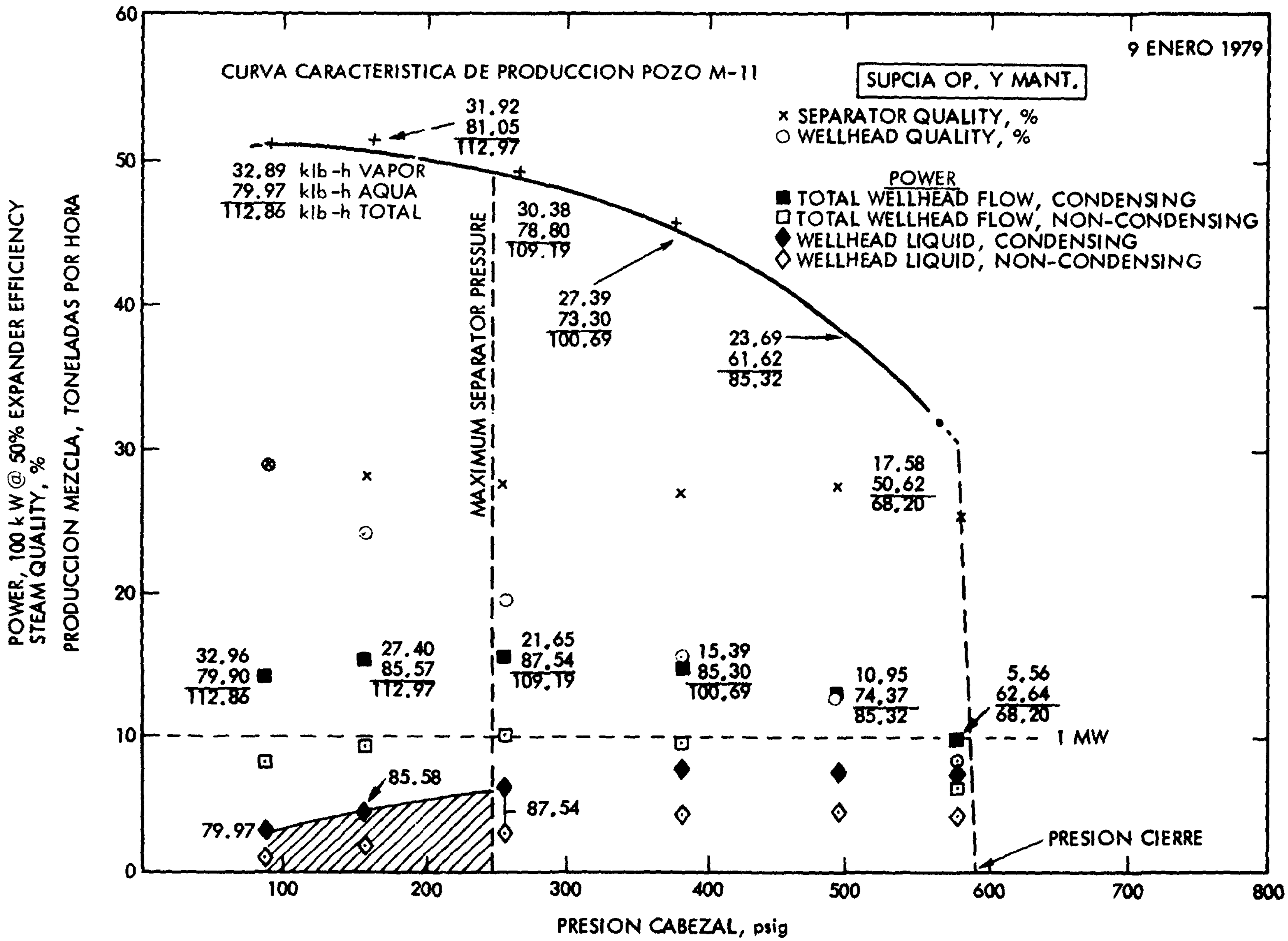

Figure 8-1b. Production and Test Opportunity Curves and Data for Well M-11

SECTION IX

REFERENCES

1. Installation, Operation, and Maintenance Manual, 1-MW Geothermal Power Conversion System, HPC Model No. 76-1, Hydrothermal Power Co., Mission Viejo, California, prepared by HPC under JPL Contract No. 954404.

2. JPL Test Support Equipment for H.S.E. Power Plant in Utah, August 1979 (compiled by R.V. Smith).

3. JPL Data System Hardware Manual for HSE Power Plant Testing, June 1981 (compiled by R.A. McKay and W.S. Wuest).

4. Wahl, E.P., Wahl Co., Documentation of Selected Data Acquisition and Analyses Program for 1978-1979 Helical Screw Expander Tests in Utah, JPL Internal Report 5030-513, August 1981 (Proprietary).

5. Final Report: Design, Fabrication, Delivery, Operation and Maintenance of a Geothermal Power Conversion System, prepared by HPC under JPL Contract No. 954404.

APPENDIX A

DESCRIPTIVE SPECIFICATION FOR GEOTHERMAL POWER CONVERSION SYSTEM SUPPLIED BY HYDROTHERMAL POWER CO.

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DESCRIPTIVE SPECIFICATION

for

GEOTHERMAL POWER CONVERSION SYSTEM

supplied by

HYDROTHERMAL POWER CO., LTD.

Pasadena, California

May 9, 1980

The Geothermal Power Conversion System consists of a Lysholm type expander with sixteen and one-half (16.5) inch diameter rotors, a speed reducer and an alternator, complete with all necessary auxiliary equipment and accessories required for use as a geothermal wellhead electrical generating plant. The drive train is a skid mounted, factory assembled unit, susceptible of transport without dismantlement. Heavy tarpaulins are provided for protection of the System during shipment or site storage. The Contractor's predictions of System performance are set forth in Appendices 1 and 2 herewith. The System includes the following assemblies, sub-assemblies and components:

I

Main Drive Train

The main drive train is mounted and aligned on a structural steel base pad or frame. The basic envelope is 6 ft. in width, 8 ft. 1" in height, and 25 ft. in length; the weight is approximately 25,000 lbs. The main drive train is exposed for ease of interfacing with process piping, lubrication oil console, and electrical switchgear. The equipment is designed for outdoor, unattended operation for extended periods. The main drive train consists of the following sub-assemblies:

(Prime Mover)

The prime mover is a Lysholm-type machine designed for operation as a high enthalpy brine expander having the following features:

1. A fabricated steel housing with porting to provide for a variable volume ratio. The housing incorporates a gate-type governing valve that controls this variable volume ratio. The inlet port is an 8-inch, 300 lb., ANSI raised-face flange. The maximum allowable operating condition is 625 psig at 500° F.

2. The low-pressure end is of stainless steel with a 24-inch, 150 lb., ANSI raised-faced flange.

3. The shaft seal assemblies consist of a combination of segmented carbon seals, floating ring seals, and labrinth seals. Oil is maintained behind the segmented carbon seals at a pressure slightly higher than the flush water pressure to prevent water intrusion into the oil system.

4. Radial bearings are pressure-lubricated, tilt-pad type sized for moderate to low specific bearing pressure. Thrust bearings are large, sturdy, self-equalizing type of conservative design for long life. One hundred ohm platinum resistance temperature detectors are provided on all bearings.

5. Two 1 1/4-inch, threaded, plugged, inspection holes are provided in the rotor bores with provisions for measuring rotor wear.

6. Rotors are machined from solid, one-piece forgings to provide the maximum practical bending strength.

7. Rotor construction is suitable for 100 psi pressure differentials at rotor speeds up to 5,000 RPM.

8. Hard-surfaced rotor tips and end faces are provided.

9. A jacking motor is provided to slowly rotate the prime mover during periods of startup and shutdown.

The prime mover housing is hydrostatically tested according to the ASME Boiler and Pressure Vessel Code. The inlet and high pressure regions are tested to meet or exceed a 300 lb. ANSI rating. The exhaust and low pressure regions are tested to meet or exceed a 150 lb. ANSI rating.

(Speed Reducer)

A suitable speed reducer is provided and is flexibly coupled to the prime mover and to the alternator. The speed reducer is a parallel shaft horizontal offset design having sleeve type bearings. Lubrication is provided from the main lubrication console. The high and low speed couplings are self-aligning gear type with sealed grease lubrication. The low speed coupling is of the shear-pin type. The couplings are designed to operate for 20,000 hours before recommended disassembly for an alignment check and re-lubrication. The speed reducer is generously sized for an extended life of greater than ten years before overhaul. Gear sets for three gear ratios, 5000/1800, 4000/1800 and 3000/1800 rpm (approx.) are supplied with the gearbox.

(Alternator)

The alternator is a continuous duty 1000 KW, 1250 KVA, 0.8 p.f., 1800 rpm., 3 phase, 60 HZ, 480/277 volt, 4 lead, 2 bearing, drip proof, enclosed machine suitable for operation in a desert environment, and having a directly connected brushless exciter and a solid state voltage regulator. The alternator bearings are of the antifriction type with double shields and are lubricated at the factory. The alternator bearing is of a design capable of ten years of continuous operation. Two 100 ohm platinum resistance temperature detectors are installed in each phase of the windings to make possible a continuous indication of alternator temperature. A 100 ohm platinum resistance temperature detector is installed on each bearing. To reduce noise, the cooling fan is ducted and shrouded away from direct ear contact.

II

Oil System

The oil system provides bearing lubrication as well as cooling for the prime mover and the speed reducer. It also provides oil for the shaft seal needs and the hydraulic needs for the speed governor and safety shutoff mechanisms. The oil system also includes a heat exchanger and other provisions necessary to maintain the prime mover and the speed reducer at proper operating temperatures by transfer of heat from the oil to the surrounding atmosphere. A fully automatic greasing system is provided for the lubrication of all critical surfaces or bearings within the brine inlet and governor control valve. The oil system includes the following subassemblies and components:

(Lubrication Console)

1. 300-gallon reservoir with sight gauge, breather, and fill cap
2. Duplex filter and transfer valve
3. Forced draft oil-to-air heat exchanger
4. Oil pump directly connected to speed reducer at 1800 rpm
5. All associated piping, temperature and pressure regulators, gauges, and switches

(Shaft Seals)

1. Booster oil pump, filter, accumulator and regulators to shaft seals
2. A flush water pump, duplex filter with transfer valve, and flow meters to feed one GPM of suitable flush water to each shaft seal

3. A water-oil centrifuge to remove water from the seal oil discharge

(Auxiliary Functions)

1. Sufficient oil capacity and accessories are provided to assure proper operation of the governor and its hydraulic amplifier

2. Sufficient oil capacity and accessories including an accumulator are provided for hydraulic operation of the automatic gate shutoff valve.

III

System Control
(Speed Governor System)

The governor system has the following features and characteristics:

1. The governor is a mechanical flyball-type, flexible spline connected to the female rotor of the prime mover.

2. The governor output is amplified through a hydraulic servo mechanism for operation of the governing valve located in the prime mover inlet port.

3. There is a means for adjustment of the governor with provision for remote control from the electrical control box.

4. The governor control mechanism provides means for either isochronous control or droop control at the election of the operator. The accuracy of control in either case is within plus or minus one quarter (1/4) of 1% of the speed set or selected by the operator.

(Automatic Gate Shutoff Valve)

The automatic gate shutoff valve is wired for automatic fail-safe operation wheneve there is a dropout of the electrical signal required to hold it open. The generator output breaker trips open also with a dropout of the electrical signal due to underspeed.

Provisions are made for actuation of the automatic shutoff valve in consequence of any one or more of the following conditions, any one of which will trip and fully close the automatic gate shutoff value within fifteen (15) seconds:

1. Underspeed
2. Oil supply overtemperature
3. Oil supply underpressure
4. Shaft seal low differential pressure
5. Shaft seal low flush water flow
6. Excessive vibration
7. A·tuation of manual stop switch

Provisions are also made for actuation of the automatic shutoff valve in consequence of any one or more of the following conditions, any one of which will trip and fully close the automatic stop gate valve within one (1) second:

1. Overspeed
2. Actuation of manual emergency stop switch.

Relays are provided for remote actuation of both the stop and emergency stop switches.

IV

Electrical Systems

The Geothermal Power Conversion System is designed for starting without any external electrical power source. Batteries are provided to energize the safety shutoff circuit during startup and during normal operation. During operation, all necessary electrical energy, including that for battery charging, is provided by the System itself. All of the electrical lines, connections and contacts are protected from the corrosive salts and gases prevalent in geothermal environments. Protection for all instrumentation and signal wires is provided by conduit, gutter or tray as appropriate for the protection and isolation of such circuits within the perimeter of the Geothermal Power Conversion System. The electrical system includes the following subassemblies and components:

(Alternator Control and Protection)

The alternator is provided with all necessary or required protective and control devices requisite for safe operation. Accordingly, an output circuit breaker complete with solid state protective devices for circuit fault, ground fault and thermal overload conditions is provided for the main load. The output circuit breaker has a 120V AC shunt trip coil. In addition, a 400 amp., 480 V., 3 phase breaker panel is provided for possible power needs at the geothermal plant site. A separate 120 volt output breaker is provided for all inhouse usage.

The alternator is provided with a control box or console having provisions for the measurement of alternator frequency, voltage, current, power output, and kilowatt hours. A current transducer and a power transducer each provide 4 to 20 MA output. Indicating meters are provided within the control box. Means are also provided there for the convenient connection for external recording of amperage and voltage. The control box also contains an elapsed time meter, necessary relays and timers, as well as the voltage regulator and a remote governor control switch. A 10 KVA single-phase transformer with 110/240 volt output together with output circuit breakers for the control of all electrical energy (station power) used for operation of the System is also provided. The arrangement of the control box panel is generally in accord with JPL Drawing No. SE/60-0 that appears in the JPL ELECTRICAL STANDARDS published in June 1975 by the JPL Facilities and Engineering Construction Office.

(Remote Monitoring)

A terminal box containing a terminal strip is provided to facilitate the remote monitoring of the following:

1. Alarm and sensor contacts giving indications of improper speeds, pressures, temperatures or vibrations

2. Remote circuit breaker trip mechanism

3. Station power (120/240 volt)

4. Temperature sensors

5. Bearing load sensors

6. Amperage transducer

7. KW transducer

8. KWH pulse

9. Voltage

10. Frequency

11. 24 Volt DC Supply.

(Remote Control)

A terminal box containing a terminal strip is also provided to facilitate the remote control of the following:

1. Voltage

2. Frequency

3. Normal stop

4. Emergency stop.

V

Inlet Piping

The System includes adequate means for support and flexible coupling of the upstream piping so as to minimize any mechanical loading of the prime mover. The inlet piping is capable of safe handling of geothermal fluids at pressures up to 625 psig and temperatures up to 500°F. All inlet piping is hydrostatically tested to the ASME Boiler and Pressure Vessel Code to meet or exceed a 300 lb. ANSI rating. The inlet piping of the System includes the following components:

1. 8-inch, 300 lb. ASA gate start and stop valve
2. 8-inch, 300 lb. ASA automtic gate stop valve, pneumatically-hydraulically actuated
3. Flex-coupling at prime mover inlet, 8-inch, 300 lb. ASA rating
4. Burst-type bypass plus relief valve.

VI

Drawings

The Geothermal Power Conversion System is furnished in conformity with the following drawings as prepared by the Hydrothermal Power Co., Ltd.

Drawing Number	Issue Date
1. B-13	As revised 1-18-78
2. B-14	As revised 5-9-80
3. B-20	As revised 5-17-80

APPENDIX B

FINAL CALIBRATION DATA: 1979

Stored data a & b of a+bX(volts)=X[J] is:

11/15 16:56:26

1	-245.294000	1258.198000
2	-250.747574	1249.569151
3	-12.460000	62.750000
4	-43.602123	225.554822
5	-24.144700	124.466500
6	-11.020074	204.834084
7	-255.806175	1255.828359
8	-136.919128	636.983885
9	-115.192100	617.504600
10	-100.000000	500.000000
11	-100.000000	500.000000
12	-126.258998	574.833496
13	-12.493722	62.819149
14	0.000190	1.001720
15	0.000470	1.001100
16	-35.460000	175.540000
17	-35.813000	176.819600
18	-3.608502	988.630746
19	-3.608502	988.630746
20	-3.608502	988.630746
21	-3.608502	988.630746
22	-3.608502	988.630746
23	-3.608502	988.630746
24	-3.659743	989.119683
25	-3.509639	988.630746
26	-3.560831	989.119683
27	-0.981580	987.500000
28	-69.319632	990.380559
29	-0.990770	988.810000
30	0.000000	599.500000
31	0.000000	1499.600000
32	55.000000	9.995300
33	0.000000	1197.870000
34	365.283262	138.970231
35	373.685473	143.517940
36	-3.608502	988.630746
37	-3.608502	988.630746
38	-3.608502	988.630746
39	-3.608502	988.630746
40	366.491630	138.899373
41	355.625663	143.517151
42	-684.150000	3684.150000
43	-642.990000	3642.990000

APPENDIX C

TEST SITE SELECTION PACKET

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JET PROPULSION LABORATORY *California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91103*

June 10, 1976

Refer to: 383-RAM:nhs
383HSE-76-56

The Jet Propulsion Laboratory (JPL) and Hydrothermal Power Company, Ltd. (HPC), with the support of the U.S. Energy Research and Development Administration Division of Geothermal Energy (ERDA-DGE), are preparing to evaluate the HPC Electrical Power Generating System (U.S. Patent No. 3,751,673) on geothermal fluids at liquid dominated field sites which are to be selected. The project will feature the helical rotary screw expander in a 1250 kVA power system module now being built by HPC, complete with generator and all associated controls and equipment. The expander size is a compromise--large enough to be commercial and yet small enough to permit a broad test program using existing wells. JPL, as manager of the project, is preparing an instrumentation and data console, a dummy load, and controls for manipulating the load and the fluids.

The purpose of this communication is twofold: first, to open a technical dialogue with those organizations having a hydrothermal geothermal resource under production in order to explore the prospects of testing the geothermal energy conversion system at their site and, second, to inform the geothermal resource companies and other interested organizations of the nature and status of the evaluation project. As an aid to the dialogue, a questionnaire is submitted herewith for your consideration.

The project is a logical extension of the development and field testing carried out by HPC with their 62.5 kVA prototype. The objectives are to determine the performance characteristics of the expander and power system over a broad range of operating conditions and also to examine the concept of the wellhead power plant. Another objective is to bring about participation and interaction with the geothermal electric power community in the project. The investigation will include corrosion, erosion, scale formation and control, endurance testing and equipment life predictions, and the problems of interfacing a wellhead plant with a well and with an electric grid. The work leads through an applications systems study to the design, construction, and testing of a complete pilot miniplant in the 5-7 MW size.

The research, planned in five phases, is expected to provide the performance maps for this new equipment application for the wide range of conditions which are found in liquid dominated geothermal fields. It will deal with the questions of performance optimization, expander staging and ultimate size, effects of vapor fraction and non-condensibles, exhaust pressure and heat rejection, brine management and waste disposal, the wellhead power plant concept vs centralized plants, mixed systems and multiple applications, and costs. The goal is the optimum exploitation of the resource.

A concise schedule of the total project outline and a discussion of the expander are contained in the paper Helical Rotary Screw Expander Power Systems, a copy of which is enclosed. A schedule for the first two phases of the project is shown in more detail in Figure 1, which is included with the enclosed questionnaire. An outline of the test plan for the evaluation of the expander in the second phase of the project is also included.

In the interest of hastening the site selection process and on the basis of first hand experience and the advice of others who have faced the same problem, such topics as liability and well use agreements are not being overlooked but are deferred until later. I hope you find the questionnaire interesting. We would appreciate your response by June 28, 1976. Comments on any points not covered in the questionnaire will be welcomed. If you have any questions please phone me on (213) 354-3107.

Very truly yours,

Richard A. McKay, Ph.D.
Principal Investigator
Helical Screw Expander Project

Enclosures (5)

cc: C. McFarland, ERDA
C. Mohl, JPL
R. Sprankle, HPC

June 10, 1976

SITE SELECTION QUESTIONNAIRE
FOR

TESTING A 1250 kVA HELICAL ROTARY SCREW EXPANDER ELECTRIC POWER GENERATING SYSTEM ON GEOTHERMAL BRINE

The Jet Propulsion Laboratory (JPL) is working with Hydrothermal Power Co., Ltd., (HPC) to evaluate the HPC Electrical Power Generating System (U.S. Patent No. 3,751,673) in a project which will test a 1250 kVA power system module on geothermal brine. The project is funded by the U.S. Energy Research and Development Administration through the Division of Geothermal Energy. The testing, conducted by JPL, will entail operating the expander at selected loads and speeds over a wide range of wellhead conditions, with the expander exhausting to atmospheric pressure and above. The test conditions and the results of the tests will be presented in open reports and seminars at appropriate points during the project. (For more details, see the Test Plan and the Schedule).

The purpose of this questionnaire is to invite the consideration of your organization to provide a test site and to participate in the preparation of the test site, and the planning and test operations. In general, comments from the geothermal utilization community will be welcomed.

Please put in parenthesis those responses which are proprietary, if any. Please return the questionnaire to

Dr. Richard A. McKay
Bldg. 122 Room 123
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

In case of questions, phone (213) 354-3107.

1. Salinity or total dissolved solids (TDS). Two sites are needed, one having low saline brine of up to 30,000 ppm TDS and one having hypersaline brine, greater than 200,000 ppm TDS. Testing at the low saline site is scheduled to begin about June 1977 and at the hypersaline site about December 1977. Site preparation in advance of the testing will be required at each site.

Is your organization interested in providing a site? Yes ______ No ______

Would a different salinity range be preferable to your organization?
Yes ______ No ______

Approximate salinities available: ____

____

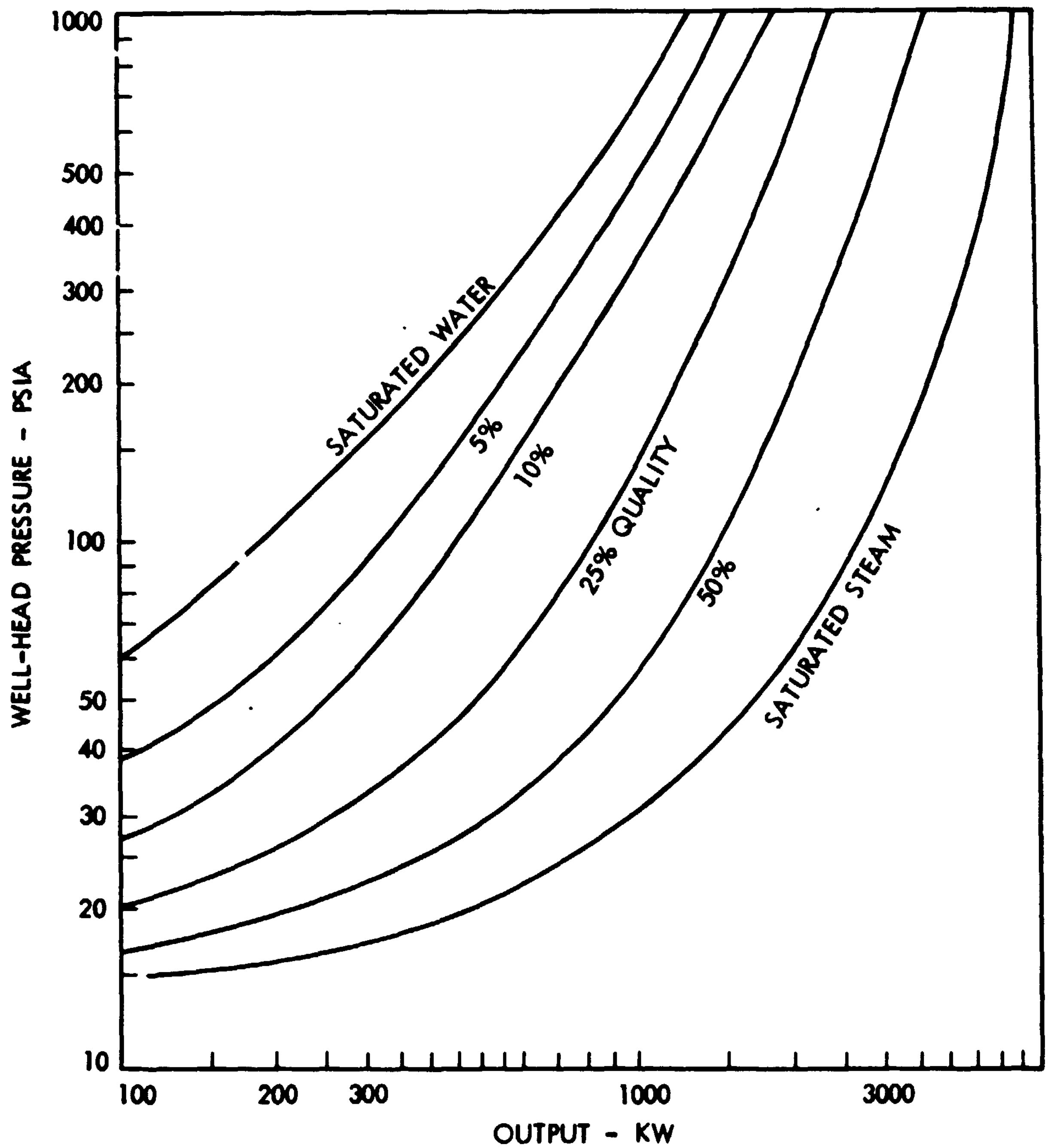
Is a brine analysis presently available to this project? Yes ______ No ______
If not, under what circumstances would such information be available?

2. Cooperative research. An important objective of this expander evaluation project is the direct involvement of industry. The expander will be evaluated as part of a modular geothermal power system which will be built by Hydrothermal Power Co., Ltd., who have brought the helical screw expander geothermal power system to its present state of development. The direct participation of representatives from the geothermal user industry in the site preparation and evaluation testing is very desirable. The availability of such participation along with the availability of suitable sites is especially welcome.

Is your organization interested in such participation? Yes ______ No ______

3. <u>Wellhead conditions and flowrate</u>. The expander will be rated for inlet conditions of 625 psig at 500°F. Thus it can operate directly on any well having wellhead pressures and temperatures which do not exceed these conditions. Since it is desirable to characterize the expander over as wide a range of operating conditions as possible, wells which produce at wellhead pressures up to 625 psig are preferred. By throttling between the well and the expander inlet, all lesser wells down to the atmospheric boiling temperature can be simulated. (The steam fraction in the feed to the expander can be adjusted with the aid of a separator).

The theoretical relationship between expander inlet conditions, fluid throughput, and output power for any mixed flow expander operating at 70% machine efficiency and expanding to approximately atmospheric pressure is shown by the curves in the figure, next page. Please state the relationship between flowrate, wellhead temperature or pressure, and steam fraction for your well so that the operating range of the expander permitted by the candidate wells can be determined. If this information cannot be released at present, under what circumstances would such information be available?



ASSUMPTIONS:
1. TOTAL WELL FLOW RATE, 100,000 LB/H.
2. EXHAUST PRESSURE, 15 PSIA.
3. 70% EXPANDER EFFICIENCY.

4. Coolant brine or water. One option in the test plan outlines the use of a coolant stream to condense the steam in the expander exhaust in order to facilitate measuring the brine throughput and the exit enthalpy for the expander. For tests involving expansion to atmospheric pressure, a maximum coolant rate of about 660,000 lb/hr (1320 gpm) at 100°F is predicted. The predicted rate will be smaller if the coolant is available at lower temperatures. It is assumed that the coolant could be surface water or brine which is recycled from a heat rejection pond or a cooling tower. Please state if coolant in the above amounts will be available at your site and from what source.

Comments:

5. Production reliability. In order to meet the wishes expressed by some potential geothermal industry users, the test plan may call for continuous operation of the expander over a period of three months at both sites.

Does your site have sufficient production to permit such a test? Yes ___ No ___
(The use of a coolant stream during prolonged operation of the expander is optional).

Recognizing that the follow-on work proposes to do endurance testing over a period of two years, do you concur with the two three-month on-line test elements in the present test plan? Yes ______ No ______

Comments:

6. Waste disposal. This project has assumed that the disposal of the waste brine, steam, and gases which arise during the tests can be accomplished at the site in a manner so as not to impede the testing of the expander. In In other words, disposal rates are assumed to be adequate and locally acceptable. Is this the case? Yes ______ No ______

Comments:

7. Noise. This project has also assumed that noise arising from the tests, such as, for example, from an emergency bypass, is compatible with the test site. Are there any special limits or considerations? No ______ Yes ______

Comments:

8. <u>Site permits</u>. This project has assumed that all local, state, or federal permits required to operate the site for test purposes will have been obtained by the site operator.

Comments:

9. <u>Condition of well and hardware</u>. Are the ages and condition of the well, casing, valve tree or other hardware expected to present any special problem to this project? Yes ______ No ______

Comments:

10. <u>Turn-down and shut-down requirements</u>. The screw expander power system contains its own flow control valve and will be coupled directly to the well. Are there any special turn-down and shut-down requirements for the well?

11. <u>Surging</u>. Because the expander will be self-regulating to provide a steady power output, steady inlet conditions are desirable. What information is available concerning surging at the wellhead?

12. Entrained solids. Although some entrained solids have passed through the prototype expander with no evidence of damage, such solids are assumed to pose a hazard to the equipment. Therefore a protective trap is probably desirable. What is known about the amount and size of sand and gravel, etc., in the brine?

13. Dissolved gases. Large quantities of dissolved gases such as CO_2, H_2S, and NH_3 will affect the brine chemistry, the expander performance, and the test procedures. What is the fraction of these gases in the well fluid? If this information cannot be released at present, under what circumstances would such information be available?

14. Chemistry laboratory. Is a brine chemistry laboratory available at or near the site? Yes ______ No ______

15. Corrosion data. Are corrosion data available for the candidate brine to aid in material selection? Yes ______ No ______

16. Shop facilities. Are shop facilities available at or near the site? Yes ______ No ______

17. Test equipment. Might items of test equipment such as valves and separators be available for use in the testing of the expander? Yes ______ No ______

18. Electric power. Is commercial electricity available at the test site for an estimated test instrumentation load of less than 2 kW? Yes ____ No ____

19. Topography and accessibility. The test equipment will include a skid-mounted power plant module about 6' x 22', weighing approximately 24,000 lb, which should be placed near the well, and 8' x 20' instrumentation van which should be located nearby. Smaller companion pieces include an oil console for the power plant and an air-cooled load bank. Will the accessibility and the topography at the site be a problem? Yes _____ No _____

Comments:

20. Restricted or open site. Open sites will be required for the testing of the helical rotor expander, with visitor control to be arranged by the site operator and JPL. Is an open site possible at your field? Yes ___ No ___

21. **Visitor transportation**. What is the name of the nearest commercial airport and approximate travel time to the site? Are rental cars available at the airport?

22. **First aid**. What is the name and location of the nearest first aid station and the nearest hospital?

23. **Units of measurement**. Will the use of the International System of Units throughout this project be welcomed by your organization? Yes ____ No ____

HELICAL SCREW EXPANDER PROJECT

TEST PLAN OUTLINE

TEST PURPOSE

The central purpose is to evaluate the performance of the Lysholm type helical rotary screw geothermal expander which Roger Sprankle has developed and incorporated into the HPC Power System, with the testing to be done on geothermal fluids at liquid dominated sites over a broad range of operating conditions. Although the investigation will deal with corrosion, erosion, scale formation and control, component durability, etc., this outline discusses only the determination of engine efficiency.

TEST PLAN

Variables

The selected variables for the expander are a) inlet pressure; b) inlet vapor fraction; c) outlet pressure, d) speed, and e) load.

a. Inlet Pressure. The expander is designed to accommodate all wellhead pressures up to 625 psig. In the testing of the expander, wellhead pressures less than the pressure of the test well can be simulated by throttling to the desired lower pressure by means of a throttle located between the well and the expander.

b. Inlet Vapor Fraction. The vapor fraction in the expander inlet stream can be varied by selectively bleeding off either vapor or liquid.

c. Outlet Pressure. Most of the measurements will be made with the expander exhausting to atmospheric pressure. Provisions for a back pressure plate in the expander exhaust area are included in the design to permit expansion to higher pressures.

d. Speed. The high speed or male rotor will be operated at fixed speeds of approximately 3000, 4000, and 5000 RPM as determined by a gearbox through which the expander will drive a 1250 kVA alternator. The speed of the alternator will be held constant at 1800 RPM by the expander governor and an internal flow control valve.

e. Load. The load will be adjusted manually in 50 kW increments over the desired test range.

Engine Efficiency

For an expander operating under steady state conditions with negligible heat loss, the following well known equations apply:

$$w = \frac{P}{\dot{m}} = h_1 - h_2 = \eta(h_1 - h_{2s}) \qquad \text{eq. (1)}$$

where w = work

P = power

$\dot{m}$ = mass flow rate

h_1 = inlet specific enthalpy

h_2 = outlet specific enthalpy

h_{2s} = outlet specific enthalpy which would result if the expansion were isentropic to the same outlet pressure

η = engine efficiency

The engine efficiency compares an actual expander with an ideal one for the same inlet and outlet conditions and throughput.

Measurement

In general the fluid streams of interest are mixtures of liquid and vapor, and accurate measurement of mass flow rate and enthalpy are difficult. It is advantageous to make the measurements at atmospheric pressure.

The strategy proposed is to determined P, $\dot{m}$, and h_2, and thus h_1, since from eq. (1)

$$h_1 = \frac{P}{\dot{m}} + h_2 \qquad \text{eq. (2)}$$

The value of h_{2s} is calculated next, using the thermodynamic properties of water from the Steam Tables and making corrections for the other constituents in the fluids. This allows the calculation of engine efficiency, since from eq. (1)

$$\eta = \frac{P}{\dot{m}(h_1 - h_{2s})} \qquad \text{eq. (3)}$$

The expander shaft output power will be determined accurately by measuring the electrical output of the 1250 kVA calibrated alternator which will be driven by the expander through a calibrated gearbox. For the determination of $\dot{m}$ and h_2, at least two options will be considered.

Option 1. Separate the exhaust fluids from the expander into liquid and vapor streams and measure the flow rate of each. The desired flow rate is the sum of the two, and the specific enthalpy h_2 can be determined from the flow rates and states of the separate streams.

Option 2. Mix the exhaust fluids with cold water or brine in amount sufficient to condense all of the steam. From measurements of the state and flow rates of the coolant stream and the combined stream, a material and energy balance permits the calculation of the enthalpy and flow rate of the expander exhaust.

These two methods, used at atmospheric pressure, are both applicable to tests involving expansion to above atmospheric pressure because the subsequent throttling into the measuring apparatus entails no change in either the enthalpy or flow rate of the exit stream. Similarly, the inlet enthalpy h_1 can be measured by replacing the expander with a throttling bypass flashing into the measuring apparatus, provided the flowrate can be made to match the expander test conditions.

Option 3. To be explored.

The selection among the options and the details of the test plan will be influenced by the nature of the geothermal fluids and other aspects of the test sites. For example, the non-condensable gas content and the scale formation tendencies of the brine following flashing are two of the important considerations. It is likely that a single test plan be preferred which is applicable to both test sites.

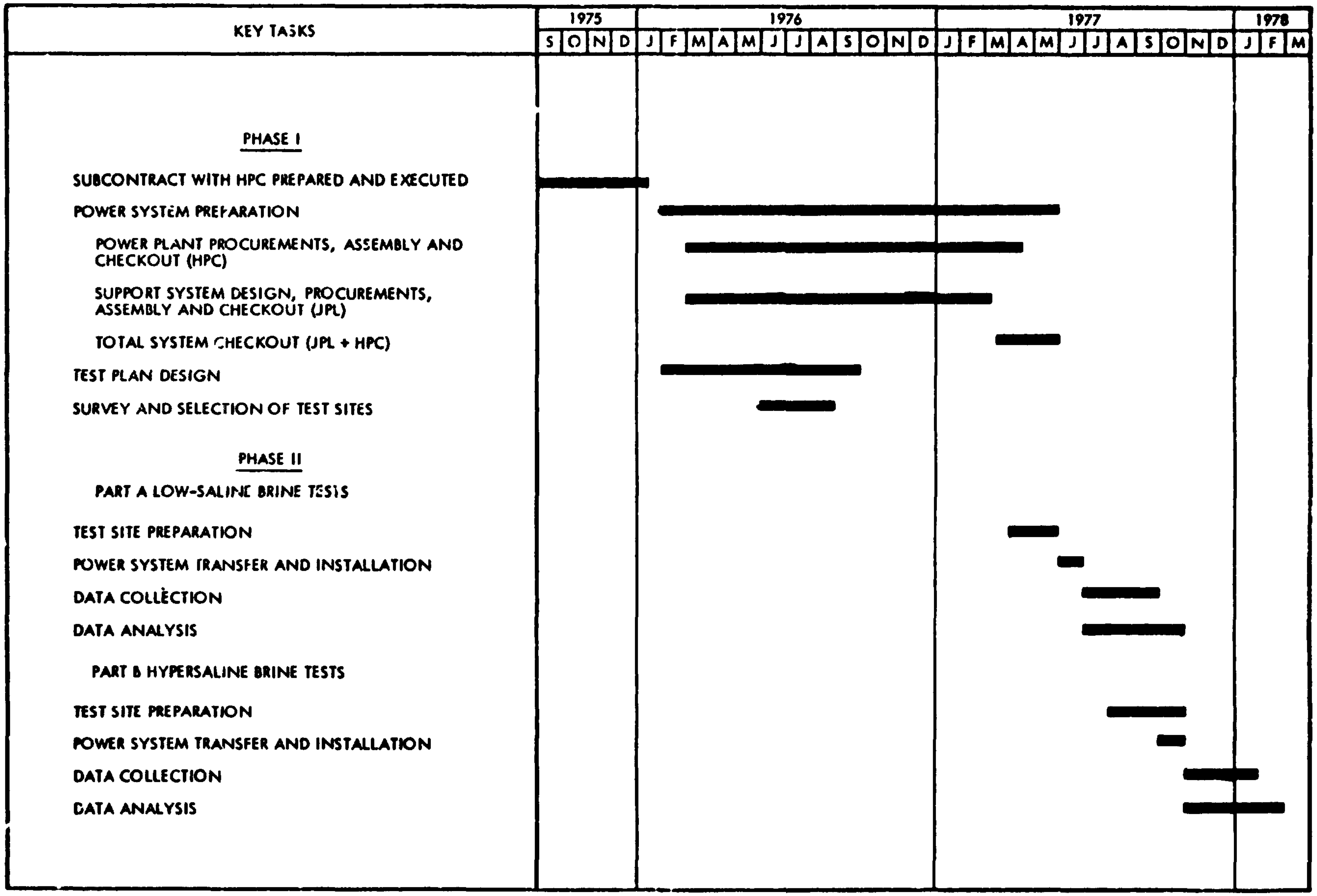


Figure 1. Helical Screw Expander Project Abbreviated Schedule

June 10, 1976
Revised June 15, 1976

Questionnaire Distribut'on List
for Selection of Test Sites

HELICAL SCREW EXPANDER PROJECT

GROUP A Organizations Known to Have Prospective Sites

Mr. E. A. Lundberg
Regional Director
Bureau of Reclamation
P. O. Box 427
Boulder City, NV 89005

Attention: 700

Sr. Ing. Jorge Guiza
Jefe del Departamento de Recorces Geotermices
Comision Federal de Electricidad
Rodano #14-50, Piso
Mexico City 5, D. F.
Mexico

Dr. Charles W. Berge
Manager, Geothermal Operations
Phillips Petroleum Company
P. O. Box 752
Del Mar, CA 92014

Dr. Carel Otte
V. P. - Geothermal Division
Union Oil Co. of California
P. O. Box 7600
Los Angeles, CA 90051

Mr. Thomas C. Hinrichs
Magma Power Co.
631 S. Witmer
Los Angeles, CA 90017

Mr. Robert W. Maxwell
Manager - Geothermal
Gulf Energy & Minerals Company
Division of Gulf Oil Corporation
Gulf Bldg.
1780 S. Bellaire Street
Denver, CO 80222

Dr. Robert W. Rex, President
Republic Geothermal Inc.
11823 E. Slauson Ave.
Santa Fe Springs, CA 90670

Mr. Charles T. Condy
California Energy Company, Inc.
44 Montgomery Street
San Francisco, CA 94104

GROUP B Organizations Known to Have Geothermal Resource Interests

Mr. Bob Greider
Chevron Oil Co.
Minerals Division
P. O. Box 599
Denver, CO 80201

Mr. William M. Dolan
Amax Exploration, Inc.
4704 Harlan Street
Denver, CO 80212

Mr. Malcolm H. Mossman
The Anschutz Corporation
1110 Denver Club Bldg.
Denver, CO 80202

Dr. E. Hunter Paalman
Research Engineer, Process Development
Dow Chemical U. S. A.
Western Division
2800 Mitchell Dr.
Walnut Creek, CA 95898

Mr. J. D. Langston
V. P. - Exploration
EXXON
Box 2180
Houston, TX 77001

Mr. Ben G. Groenewold
V. P. - Exploration
Natomas International
777 S. Post Oak Rd.
Houston, TX 77056

Mrs. Alice Denman
Geothermal Energy & Mineral Corp.
P. O. Box 234
Calipatria, CA 92233

Mr. L. H. Kreisel
Imperial Thermal Products, Inc.
7380 Central Ave.
Newark, CA 94560

Mr. Jos. I. O'Neill
Joseph I. O'Neill, Jr.
410 W. Ohio
Midland, TX

Mr. R. J. Watson
Manager, Field Research Laboratory
Mobil Oil
P. O. Box 900
Dallas, TX 75221

Mr. Patrick J. Fazio
V. P. - Exploration Operations
McCullock Oil Corporation
10880 Wilshire Blvd.
Los Angeles, CA 90024

Mr. Bob Macy
Sun Oil Company
503 N. Central Expres ay
Richardson, TX 75080

Mr. Julius Babisak
V. P. - Exploration
Atlantic Richfield Corporation
515 S. Flower
Los Angeles, CA 90071

Dr. H. Tsvi Meidav
Geonomics, Inc.
3165 Adeline St.
Berkeley, CA 94703

Mr. Stan Eschner
Mgr. - North American Exploration
Occidental Exploration & Production Co.
5000 Stockdale Hwy.
Bakersfield, CA 93309

Mr. John Woffington
Exploration
Getty Oil Company
Rt. 1 Box 197X
Bakersfield , CA 93309

Mr. George Frye
Division Engineer
Burmah Oil & Gas Co.
P. O. Box 11279
Santa Rosa, CA 95406

Mr. C. R. Gerling
Sr. Staff Geological Engr.
Shell Oil Company
P. O. Box 851
Houston, TX 77001

Mr. Ronald C. Barr, President
Earth Power Corporation
P. O. Box 1566
Tulsa, Oklahoma 74101

GROUP C Organizations Affiliated with Group A

Dr. L. T. Papay
Director, Research & Development
Southern California Edison Company
P. O. Box 800
2244 Walnut Grove Ave.
Rosemead, CA 91770

Mr. James M. Nugent
Project Engineering Coordinator
San Diego Gas & Electric Company
101 Ash Street
San Diego, CA 92112

Mr. Joseph N. Baker, City Manager
City of Burbank, California
P. O. Box 6459
275 E. Olive Ave.
Burbank, CA 91510

Mr. Ken F. Mirk
Geothermal Component
Project Test Facility
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Mr. John P. Hiltabiddle
Atomics International Division
Rockwell International
8900 De Soto Ave.
Canoga Park, CA 91304

Mr. Russell O. Pearson
Systems Group
TRW, Inc.
One Space Park
Redondo Beach, CA 90278

GROUP D Organizations Known to Have Special Interest

Mr. Vasel W. Roberts
Electric Power Research Institute
P. O. Box 10412
Palo Alto, CA 94303

Mr. Edwin C. Schlender
Manager
Raft River Rural Electric Cooperative
Malta, ID

Mr. Gary Soule, Sr.
V. P. - Engineering
Sierra Pacific Power Company
501 E. Moana
Reno, NV 89502

Dr. Arthur L. Austin
Lawrence Livermore Laboratory
P. O. Box 808, L-505
Livermore, CA 94550

Mr. Hugh B. Matthews
Sperry Research Center
Sudbury, Massachusetts

Dr. Paul A. Longwell
Aerojet - General
9100 E. Flair Drive
El Monte, CA 91734

Mr. Martin Berger, President
Occidental Research
P. O. Box 310
La Verne, CA 91750

Mr. Norman P. Ingraham, Manager
Northern California Power Agency
1400 Coleman Ave.
Santa Clara, CA 95050

Mr. Gail Moulton
Sr. Geologist
Kerr-McGee Chemical Corporation
P. O. Box 367
Trona, CA 93562

Mr. Kenneth Brunot
Senior Program Manager
NSF Western Projects Office
831 Mitten Road
Burlinghame, CA 94010

Mr. Ritchie B. Coryell
National Science Foundation
1800 G Street, N.W.
Washington, D. C. 20550

Mr. Leonard J. Keller
The Keller Corporation
2650 Northhaven Road
Dallas, Texas 75229

Mr. C. R. Possell
General Ener-Tech., Inc.
833 W. Fir
San Diego, California 92101

Mr. Tallmon E. Horst
Horst Power Systems, Inc.
15850 San Bern Road
Saratoga, CA 95070

Mr. Donald J. Cerini
BiPhase Engines, Inc.
2907 Ocean Park Boulevard
Santa Monica, CA 90406

NSF-RA-N-74-159

PROCEEDINGS

CONFERENCE ON RESEARCH FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY RESOURCES

September 23 - 25, 1974
Pasadena, California

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Research and Technology

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HELICAL ROTARY SCREW EXPANDER POWER SYSTEM

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Jet Propulsion Laboratory
Pasadena, California

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Hydrothermal Power Company, Ltd.
Pasadena, California

A technical survey made by the Jet Propulsion Laboratory (JPL) led to the conclusion that an energy converter well suited to wet steam geothermal fields could be a major stimulant to the development of these energy resources. The helical rotary screw expander, developed by the Hydrothermal Power Co., Ltd. (HPC), is a very promising candidate to fill this need. JPL has proposed to evaluate and characterize the screw expander in conjunction with HPC. The work will use commercial-size equipment operating on low saline and then hypersaline brine with members of the geothermal industry participating. The helical screw expander is a positive displacement machine of the Lysholm type which can accept the untreated corrosive mineralized hot water of any quality from a geothermal well. The subjects of corrosion, mineral deposition, the expansion process, the experience to date with a prototype and the proposed evaluation project are discussed.

I. INTRODUCTION

In all the world, there are only 12 locations where electrical power is presently generated from geothermal energy, providing a total installed capacity of about 1100 MW (Refs. 1-4).* In these locations energy is available from the ground as geothermal fluid, either in the form of steam (vapor-dominated fields) or in the form of hot brine (liquid-dominated fields). In all cases, energy is converted to electrical power by means of a vapor turbine as the prime mover. In the vapor-dominated fields (four locations), the procedure is essentially simple. Dry steam from the producing wells is

*For comparison: As of 1970, the world's largest high-pressure steam-driven turbogenerator was the 1150-MW unit at the TVA power plant at Paradise, Ky. Two nuclear plant additions now under construction at San Onofre, California will be 1140 MW each.

cleaned of entrained solids, and then passed directly to turbines which drive electrical generators. In the case of the liquid-dominated fields, the brine is either flashed to liberate steam, which is then separated from the residual brine and sent to the turbogenerators (seven locations), or it is used to boil a secondary fluid (one location) which in turn is sent to turbogenerators.

At present, the four vapor-dominated fields noted above have a combined, installed electrical capacity of 806 MW or 73% of the worldwide geothermal total. The largest of these is at The Geysers in California, where Pacific Gas and Electric Co. (PG&E) is systematically adding 100 MW capacity per year on a schedule that extends through 1980. These additions represent 10% of the annual increases planned by PG&E from all sources (Ref. 3). There are no reported technical problems sufficient to hamper this schedule. The schedule is planned to allow the orderly development and exploitation of the geothermal reserve, and is possible because the steam turbine is an ideal match for vapor-dominated fields. Technological problems which are encountered there, such as turbine blade erosion and corrosion, are handled in the normal course of doing business.

Unfortunately, vapor-dominated geothermal fields are scarce. This helps to explain why The Geysers is the only such geothermal power plant location in the Western Hemisphere. Far more prevalent, by an estimated ratio of 20 to 1, are the liquid-dominated fields which produce hot water or brine. It thus follows that, all other things being equal, if there are four steam fields producing electricity, there should be 80 wet fields similarly in production instead of the mere 8 mentioned above. But all other things are not equal. The ideal match of a prime mover compatible with a liquid well effluent has been historically absent, and so the exploitation of the wet fields has been seriously hampered. It has been necessary to produce a vapor to drive a turbine, either by flashing part of the brine to steam, or by boiling a secondary fluid in a heat exchanger. In the steam-flashing process, much energy is lost in the waste hot brine which flows from the steam separators, and the throttling step itself is inherently inefficient. Similarly, in the process involving a secondary fluid, substantial energy losses are associated with the temperature difference necessary to drive the heat exchanger and with the power demands for pumping the secondary fluid. (It may be noted that the world's pioneer geothermal power plant at the vapor-dominated field in Larderello, Italy, switched from the use of heat exchangers to the direct expansion of the geothermal fluid because of these inefficiencies (Ref. 1).)

In addition, supplementary process equipment, especially heat exchangers, is expensive. Moreover, and perhaps most serious, scale formation from the brine can be severe. It must be recognized that the hot brine has been in contact with minerals for a long time and will be in near equilibrium at reservoir temperatures. Therefore, as the brine is cooled, part of the dissolved solids will precipitate, especially on cool surfaces. This explains some of the failures that have been experienced in attempts to harness the energy available in the geothermal fields in the Imperial Valley of California, where much of the U.S. field effort in geothermal development is centered. Fortunately, despite the presence of dissolved salts, the fluids are usually chemically reducing, and severe corrosion rates can be avoided by the exclusion of air and by proper selection of materials of construction.

The exploration for geothermal energy is moving forward, with numerous examples of success. For example, the well known reserve in Imperial Valley has been estimated as sufficient to support the generation of 100,000 MW for 50 years of electricity (Ref. 5). The significance of this can be inferred from the rate of consumption of electricity in California, which was about 35,000 MW in 1973 (Ref. 6) (U.S. total: 300,000 MW (Ref. 7)). Other known U.S. reserves lie explored but dormant in the Mono-Long Valley area of California, in Beowawe, Nevada, and in Sandoval County, New Mexico, among others. These reserves are all liquid-dominated fields.

The NSF report Geothermal Energy (Grant GI-34313) anticipated the production of 395,000 MW from U.S. geothermal resources by the year 2000. However, this goal is attainable only with developments not yet achieved (Ref. 8). If the resources were largely vapor-dominated, the orderly development of the geothermal power industry would be assured. But it is the liquid-dominated fields which is prevalent, and the outlook for the geothermal industry is not clear. There is an acute need for a prime mover which can operate directly on the hot brine. Such a prime mover would almost certainly be the key to unlocking much of the treasure of geothermal energy in the U.S. and in other liquid-dominated fields all over the world.

II. HELICAL ROTARY SCREW EXPANDER

A 62.5-kVA prototype geothermal power plant utilizing a new helical rotary screw expander has been developed by Hydrothermal Power Co., Ltd. (HPC). The prototype plant has been tested and demonstrated by HPC for extended periods of time as a total flow wellhead system operating on hot untreated brine or brine and steam mixtures.

The helical rotary screw expander is a machine based upon development work conducted by Alf Lysholm in Sweden in the 1930's. By the 1950's Lysholm's machinery began to see extensive commercial application as a gas compressor. This application has had continued growth to the present date with installations involving 100 MW currently in operation. Early in 1971, HPC began development work in applying the Lysholm machine as a prime mover operating on geothermal hot water and brine. This development work has continued to the present.

The screw expander is a unique positive displacement machine, which bridges the gap between centrifugal or axial flow type aerodynamic machines and reciprocating positive displacement machines. It runs in a slower speed range without the high radial loads and balance problems characteristic of turbines.

As a geothermal prime mover, the helical screw expander is a total flow machine, which can expand directly the vapor that is continuously being produced from the hot saturated liquid as it decreases in pressure during its passage through the expander. The effect is that of an infinite series of stages of steam flashers, all within the prime mover. Thus, the mass flow of vapor increases continuously as the pressure drops throughout the expansion process, and the total fluid is carried all the way to the lowest expansion pressure. The process approximates an isentropic expansion from the saturated liquid line for the total flow. The expansion within the machine can be illustrated with drawings such as Fig. 1. The geothermal fluid flows through the internal nozzle control valve and at high velocity enters the high-pressure pocket formed by the meshed rotors, the rotor case bore surfaces, and the case end face, designated by A in the two figures. As the rotors turn, the pocket elongates, splits into a V, and moves away from the inlet port to form the region designated by B. With continued rotation, the V lengthens, expanding successively to C, D, and E as the point of meshing of the screws appears to retreat axially from the expanding fluid. The expanded fluid at low pressure is then discharged into the exhaust port.

III. SCALE FORMATION, CORROSION, AND EROSION

Conditions for mineral precipitation from saturated brines within the expander occur for several interrelated reasons, including temperature decrease, pressure decrease, solvent removal, turbulence, and the presence of nucleation sites. The internal surfaces of the expander serve as mineral deposition sites. Mineral deposition on these surfaces provides several beneficial results. The thickness of the mineral layer increases until the rotor-to-rotor and rotor-to-case leakage clearances disappear and the mineralized surfaces are continually lapped; steady state is reached. The loss of leakage clearances results in substantial increase in the efficiency of the expander. This clearance removal mechanism will make possible the use of less expensive fabrication and machining procedures during manufacture, and also makes the expander self-healing in the event that scarring of the case or rotors should occur. Moreover, the mineral layer has been demonstrated to provide excellent protection of the case and rotors against corrosion. This protection will provide greater flexibility in the selection of relatively low-cost materials of construction. Similarly, there has been no evidence of erosion, either because the scale layer forms a protective coating or because the fluid velocities within the machine are not high, or both. The effects of much higher velocities by nozzling at the inlet are still to be determined for the high-pressure fields.

The lapping process associated with the minerals which are deposited on the machine surfaces within the expander is a source of suspended nuclei for additional mineral deposition and crystallization within the brine. These nuclei supplement those which form spontaneously throughout the brine in the flashing turbulent conditions within the expander. In an experimental investigation of mineral deposition carried out in October 1971, while operating a helical screw expander on Well M-10 at Cerro Prieto, HPC observed that mineral deposition occurred either almost exclusively within the expander or on the seed particles traveling with the exhaust brine. After 307 hours of operation, the deposits ranged from 5/32 in. at the expander exhaust port to 1/64 in. 50 feet downstream. In the absence of the expander, the same well and feedline plugged shut a 12-in. diameter exhaust pipe in 72 to 96 hours. An expander with an insufficient expansion ratio was used in this investigation, and some flashing occurred in the exhaust port. The present prototype expander features a larger expansion ratio so that very little flashing has occurred in its exhaust port; no scale deposit problem has been detected during over 1000 hours of testing. This characteristic of mineral precipitation occurring preferentially within the expander, either on the expander surfaces which are self-cleaning or harmlessly in suspension, is highly beneficial. The tendency to deposit scale downstream appears to be negligible, at least along an isothermal path. This is important for inter-staging as well as in waste lines.

IV. EXPANDER ENGINE EFFICIENCY

Performance tests of the 62.5-kVA prototype HPC geothermal power plant were performed August 21, 1974, on brine from Well 6-1 at the U.S. Bureau of Reclamation geothermal test facility on the East Mesa KGRA. The two tests gave results of 65 and 74% for the expander efficiency compared with an ideal machine. The test results should be considered preliminary since no attempt was made to optimize the operating conditions or the test set-up. (A report of the details of the tests is in preparation.)

Industrially, the helical rotary positive displacement machine is widely used to compress air, nitrogen, hydrocarbons, and a variety of refrigerants. As expanders, these machines are used as prime movers, accessory power drives, and for temperature reduction in gas cycle refrigeration systems. They have been demonstrated to have overall adiabatic efficiencies typically well in excess of 70% over a wide operating range and as high as 85%.

An essential to high engine efficiency is small leakage past the rotors. This requires small clearances, both rotor-to-rotor and rotor-to-case. The minute clearances brought about by the wet lapping of the mineral deposits in the geothermal expander may lead to the maximum efficiencies in this new unique application.

V. SYSTEM EFFICIENCY

Three energy conversion concepts -- the Flashed Steam System, the Binary Cycle System, and the Total Flow System -- are present contenders for producing electricity from hot-water geothermal resources. In the Total Flow System, as represented by the Helical Rotary Screw Expander Power System, the hot wellhead product follows on isentropic expansion directly from the wellhead through a two-phase expander to the exhaust pressure and temperature. This system is thermodynamically the simplest and is theoretically optimum. In several excellent papers (Refs. 9-11), it has been estimated that the Total Flow System offers a 60% efficiency gain over the other two, assuming that all systems have a 70% engine efficiency. The engine efficiencies of greater than 70%, which seem assured for the helical rotary screw expander, will give the Screw Expander System an added advantage. Moreover, the estimated 60% efficiency gain is conservative, resulting from optimistic assumptions including, for example, achieving 70% of the Carnot efficiency for the secondary loop of the Binary Cycle System, and perfect steam separation in the Flashed Steam System. Actual field experience to date indicates an efficiency advantage of considerably greater than 60% for the Helical Rotary Screw Expander Power System operating on high enthalpy brines.

VI. PROPOSED EVALUATION PROJECT

A project plan has been prepared by the Jet Propulsion Laboratory for the evaluation of the Helical Rotary Screw Expander Geothermal Power System jointly by JPL and HPC. This plan has been submitted to the Division of Advanced Energy Research and Technology of the National Science Foundation for consideration in the NSF/RANN FY 1975 geothermal program.

Initially, a modular 1250-kVA geothermal power plant incorporating an HPC Lysholm-type helical rotary screw expander as the prime mover will be constructed and then operated on total flow brine to evaluate its mechanical and thermodynamic performance. In the initial work the prime mover will be single stage, expanding to atmospheric pressure or above. Studies of its interactions with the well and an electrical grid system are planned as well as an assessment of brine scale formation, corrosion, erosion, vibration, endurance, and other mechanical problems. The work will lead to design and cost studies of a broad range of applications followed by the testing and evaluation of a completely automated versatile pilot mini-plant of 5 to 7 MW for wellhead siting in liquid-dominated fields.

Hydrothermal Power Co., Ltd. will build the 1250-kVA power system model. The ensuing research will be carried out by the Jet Propulsion Laboratory and the Hydrothermal Power Co., Ltd., first using low-saline high-enthalpy brine from an area to be selected as part of the project, and subsequently utilizing hypersaline brine in the Imperial Valley, California. It is anticipated that the brine-producing agencies or site operators will participate in the research at no cost to the project. The possibility of additional mutually beneficial research activities to be carried out jointly with other organizations as part of the project on a similar basis will be explored early in the project.

The overall project is planned in five phases to be managed by JPL in approximately the following sequence as shown in Fig. 2: (1) project presentation, power system module construction, test site selections, and research planning and preparation; (2) power system characterization and evaluation; (3) longevity testing and interaction studies with the producing well and an electrical grid system; (4) applications systems studies; and (5) design, construction, testing, and evaluation of the pilot mini-plant.

The research is expected to provide the performance maps for this new equipment application for the wide range of conditions which might be found in liquid-dominated geothermal fields. It will deal with the questions of performance optimization, expander staging, effects of brine quality and non-condensables, sink pressure and temperature, brine management, waste disposal, noise, equipment size, and costs. It will aim at optimum exploitation of the resource. The concept of the wellhead power plant will be examined in detail.

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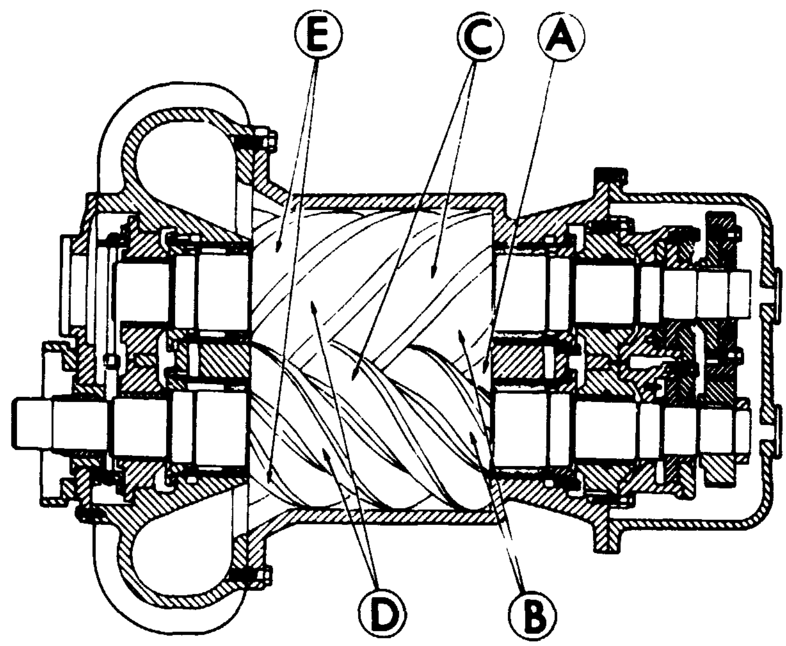
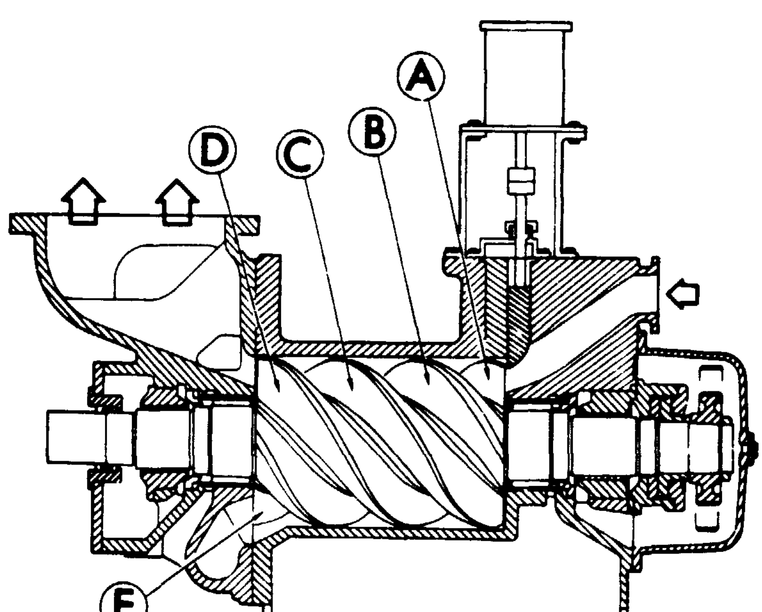
10. Austin, A. L., "Summary of LLL Presentation," Proceedings of the Geothermal Power Development Conference, University of California, Berkeley, June 18, 1974.

11. Austin, A. L., and Lundberg, A. W., "A Comparison of Methods for Electric Power Generation from Geothermal Hot Water Deposits," ASME Publication 74-WA/Ener-10 for presentation at the Winter Annual Meeting, New York, N. Y., Nov. 17-22, 1974.



PLAN SECTION VIEW



SIDE SECTION VIEW

Fig. 1. Helical rotary screw expander

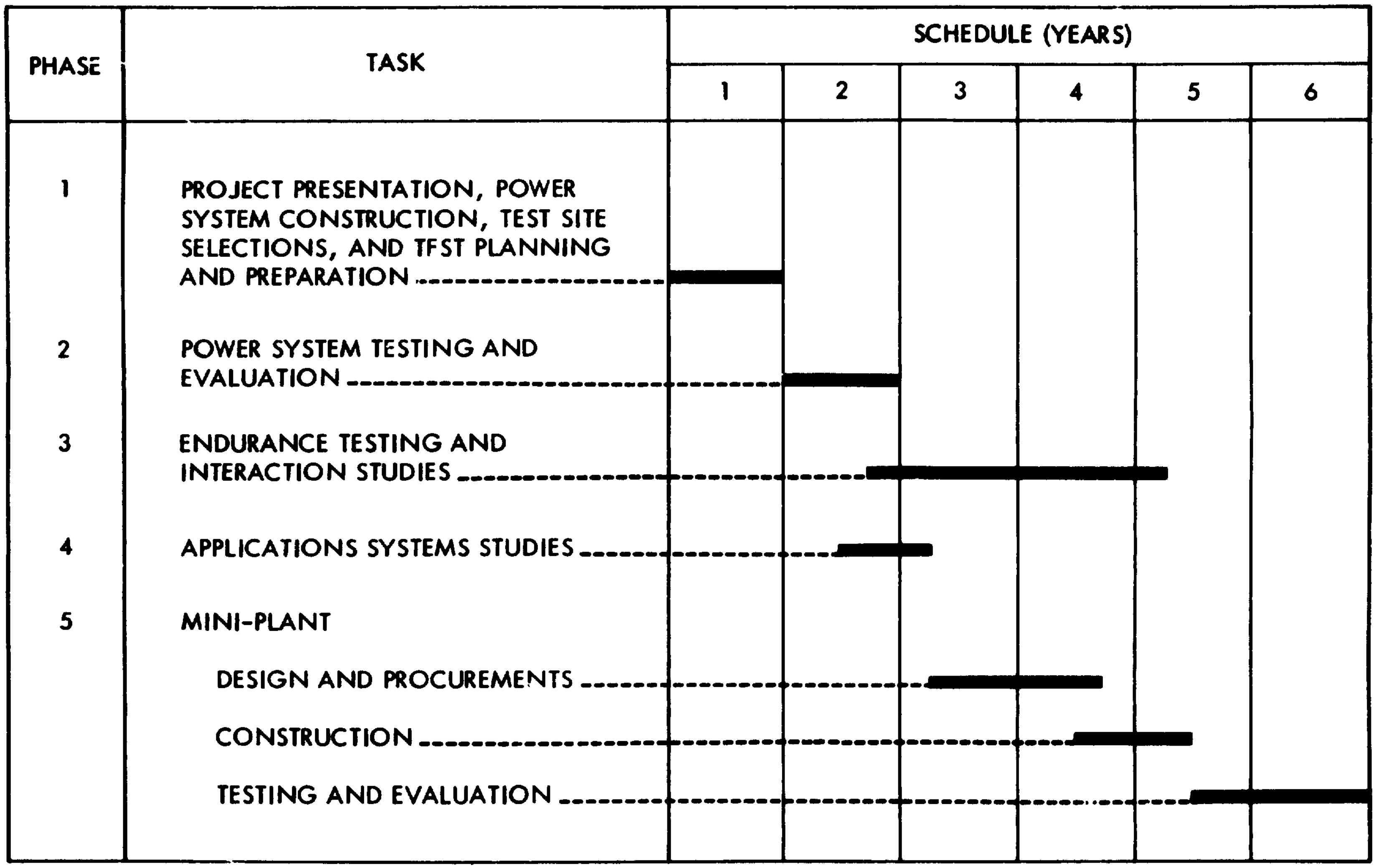


Fig. 2. Total project outline

APPENDIX D

LAND USE AGREEMENT

Revised:
September 27, 1977

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LAND USE AGREEMENT

Phillips Petroleum Company shall permit JPL to test a prototype total-flow driver, Helical Screw Expander, over a wide range of operating conditions and for an extended period of time using geothermal fluids at their test site in Roosevelt KGRA, Beaver County, Utah, in accordance with the following agreements:

(1) Phillips Petroleum Company will be the sole operator of the Flow Test Facility including the producing Well 54-3, injection Well 82-33, pipeline, separator and all associated equipment necessary to permit flow testing the well in continuous, uninterrupted fashion.

The boundary within which Phillips will maintain absolute operating authority of equipment and facilities will be identified with red bands painted on the piping.

(2) As sole operator of the Flow Test Facility Phillips will try to satisfy the range of operating conditions necessary for the conduct of tests on the total-flow device. Phillips will have absolute authority in determining the physical conditions under which the Flow Test Facility will operate and will not guarantee the range of conditions, duration, quantity or quality of fluids provided.

Phillips intends to commence sustained flow in the pipeline no later than October 1, 1977. While the system is designed to permit operation of a Total Flow Device Test Facility (TFDTF) completely independent of the Flow Test Facility, Phillips will neither delay the initiation of sustained flow for the convenience of JPL, the operator of the TFDTF, past October 1, 1977, nor guarantee delivery of geothermal fluids by that date or any date thereafter.

(3) Phillips will provide JPL, the operator of the Total Flow Device Test Facility with all information gathered related to the chemical composition of the produced fluids. No other data of any type will be furnished by Phillips to JPL.

(4) JPL will be completely responsible for the operation of the TFDTF. The facility will include the total flow device and all related monitoring and flow measuring equipment.

The boundry within which JPL will exercise control and responsibility will also be identified with red bands painted on the piping.

(5) JPL will operate and maintain the facilities in a safe, clean and workman-like manner. All safety, engineering and operating standards shall equal or exceed Phillips' standards. JPL will abide by all orders dictated by Phillips Petroleum Company when in Phillips' judgment such orders bear on the safety and/or security of Phillips' equipment and/or personnel. In the event of a dispute JPL will cease operation of the TFDTF until an agreement can be reached.

(6) JPL will provide Phillips with a daily accounting of all geothermal fluids utilized by the facility in terms of both heat and mass balance. The data provided shall be measured in a fashion which can be considered accurate within a range of $\pm$ 5%.

(7) JPL will maintain a responsible person in attendance at all times when the TFDTF is in operation.

(8) The representatives of JPL, JPL subcontractors, and any other JPL visitors to the TFDTF shall obtain Phillips permission to enter the job site.

(9) JPL shall indemnify and hold Phillips and its employees harmless from any and all claims and liabilities arising either:

(a) within the area under the control and responsibility of JPL, as described herein, or

(b) as a consequence of the conduct of operations on the premises by JPL.

Such indemnity shall specifically include claims of any nature whatsoever by employees of JPL against Phillips or its employees.

(10) The Institute agrees to maintain the following insurance with respect to performance under this Agreement.

(a) Worker's Compensation and Employer's Liability Insurance which complies with statutory requirements of the State of Utah.

(b) Comprehensive Liability insurance, including automobiles (owned, non-owned and leases), covering all liability assumed under this Contr . Such insurance shall be written for a combined single limit of not less than $1,000,000 for all deaths, injuries and property damage arising from one accident or occurrence.

The Institute agrees to furnish certificates of insurance to Phillips for the coverage required hereunder, should Phillips so request.

(11) The Institute agrees that it will not seek to hold Phillips or its employees liable for any losses JPL may incur as a result of this operation including, but not limited to, damage to its equipment.

APPENDIX E

FLUIDS USAGE INFORMATION

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NOTES FOR TABLE 4-2

The 1978 fluids usage data in Table 4-2 cover the period from March 16, 1978, which was the first day of testing, to May 30, 1978, which was the last day of testing. Most of the electrical output and usage data in the table were obtained by integrating the electrical power output and flowrate data in plots. Where available, the test data were plotted at 7-1/2 minute intervals; for purposes of integration, the plotted data points were connected by straight lines. The duration of the tests and the water disposal quantities were also recorded on totalizing meters. The totalizing meters and plot integration were generally in good agreement. Where there were discrepancies, the table contains best judgment values. Data prior to April 5 are scant because the data system was only in partial operation then.

The temperatures of the steam and water from the separator correspond approximately to saturation temperatures for the separation pressure then prevailing. These temperatures can be derived from the separator pressure which was included in the plotted data. No attempt was made to tabulate the temperatures because of the considerable variation during many of the tests, especially prior to changing the level control on the separator.

The temperature of the disposal water from the Baker tanks ranged from ambient at the start of each run, rising to approximately 197°F as the run continued, depending on its duration. The steady-state temperature correlated well with the barometric pressure and occasionally signaled weather changes.

As noted on the table, flows of water and steam bled to keep the pipes hot were not recorded; these flows were too small for the flow meters. Bleed water which accumulated in the Baker tanks was measured as part of the disposal water.

The quantity of fluids received from the separator and sent to disposal did not show any systematic relationship for most of the tests because of the change in the inventory of water in the Baker tanks. No attempt was made to express this inventory change in amount of water because the amount is nonlinear with level in part of the region of interest.

The Baker tanks were emptied into the pit on 4/12, 4/19, 4/23, 5/3 and 5/6 to permit equipment repair and at the completion of the tests.

NOTES FOR TABLE 4-3

The 1979 fluids usage data in Table 4-3 covers the period from September 3, which was the first day of testing, to November 14, the day the well was shut-in. The data in the table are from the operating log printed automatically by the data system (see Figure 2-19) and from readings of the kWh meter and Eastech totalizing flow meters logged in a notebook. The data were found to be internally consistent and are believed to fall within the 5% accuracy specified by Phillips. This rt is on a daily basis as specified in the Land Use Agreement. More frequent reporting during the test was made directly to Phillips operating personnel at the site upon request; JPL made no attempt to keep copies of these reports.

The temperature of the steam and water from the separator corresponds approximately to the saturation temperature for the pressure then prevailing. This information was not included in the table because it is already known to Phillips.

The temperature of the water returned from the Baker tanks ranged from ambient at the start of each day and rose to approximately 197°F or slightly below the boiling temperature at that altitude as the testing proceeded, depending on test duration and flowrate. This was was combined with water flowing directly from the separator to Well 82-33 for disposal.

As noted in the table, flows of water and steam bled to keep the pipes hot were not recorded because these flows were to small for measurement by the flow meters. Bleed water which accumulated in the Baker tanks was measured as part of the water returned or discarded. Some water from the Baker tanks was discarded into the pit on 9/7, 9/14, 9/15, 10/20 and 11/6 to permit equipment repair or process adjustment and at the completion of the tests.

NOTES FOR 1978 DATA PLOTS

The usage of geothermal fluids by JPL for the testing of the HSE in the Roosevelt KGRA brought the requirement that JPL report to Phillips the state and amount of fluid used and returned and the purpose on a daily basis. In 1978 this information was obtained by plotting versus time and integrating the flowrates of steam and water received from the FTF, and the flowrate of the waste water returned, the separator pressure, and the electrical power produced. The separator pressure determined the state of the fluids received, atmospheric boiling temperature established the upper temperature limit of the waste water, and the electric power produced in the testing signified the usage. The plots of flowrate were integrated with a planimeter to give the amount of fluid used each day, and the power plots were integrated to give the yield of energy. In all, 143 plots were made and all except the 32 pressure plots were integrated. The work was very tedious and time consuming. Because the results of the integration are presented in Table 4-2 and because many of the plots would be of little interest to most readers, the plots for only some of the test days are included in this report. Arbitrarily included are the plots for 4/20, 5/3, 5/12, 5/14, 5/15, and 5/22 through 5/30. The plots of 4/20 are interesting because they show the amunt of testing that was done on a day which yielded only one data set critically recorded on tape cassette while various test objectives were being attempted. Days 5/22 through 5/30 present a graphical record of the endurance testing.

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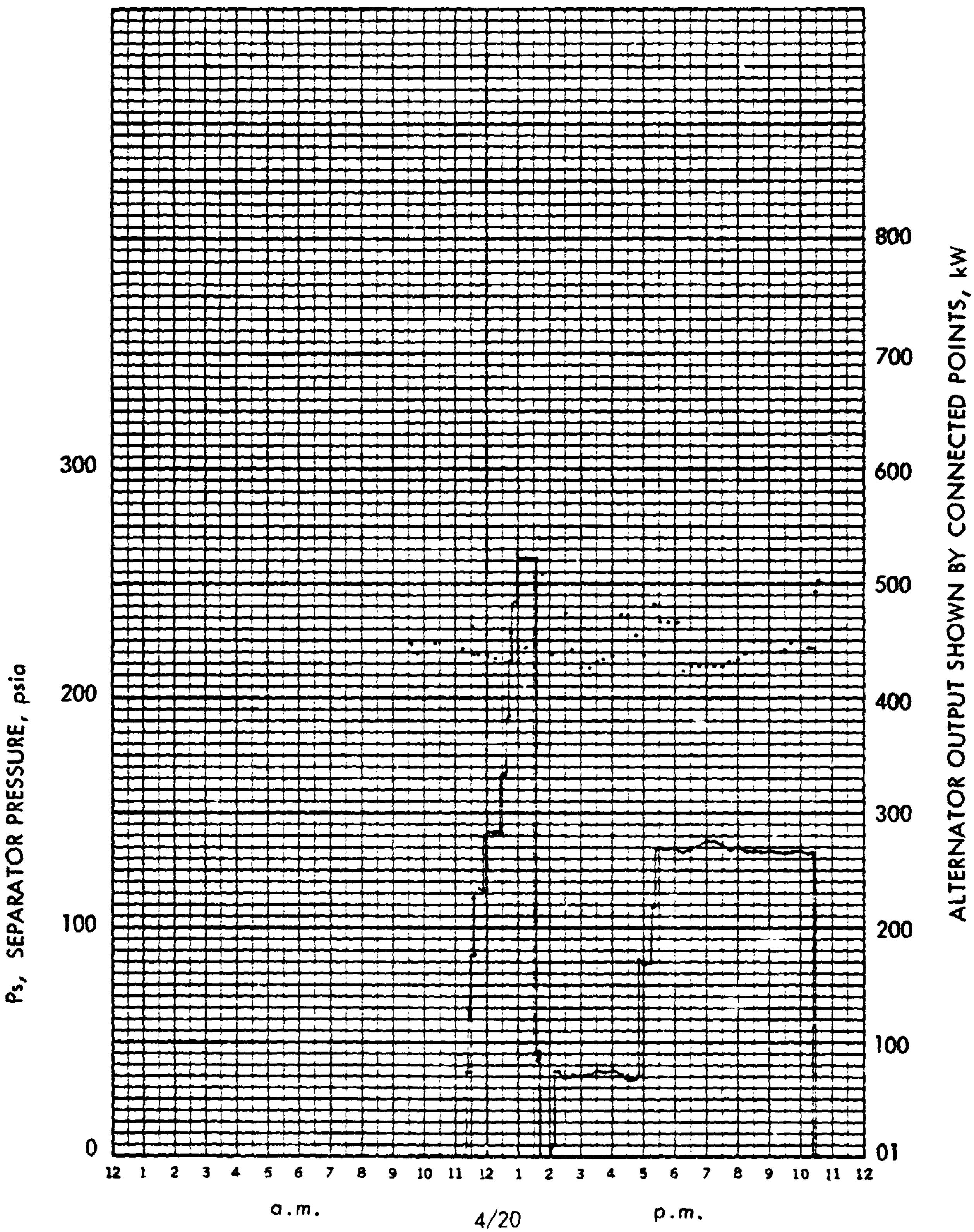

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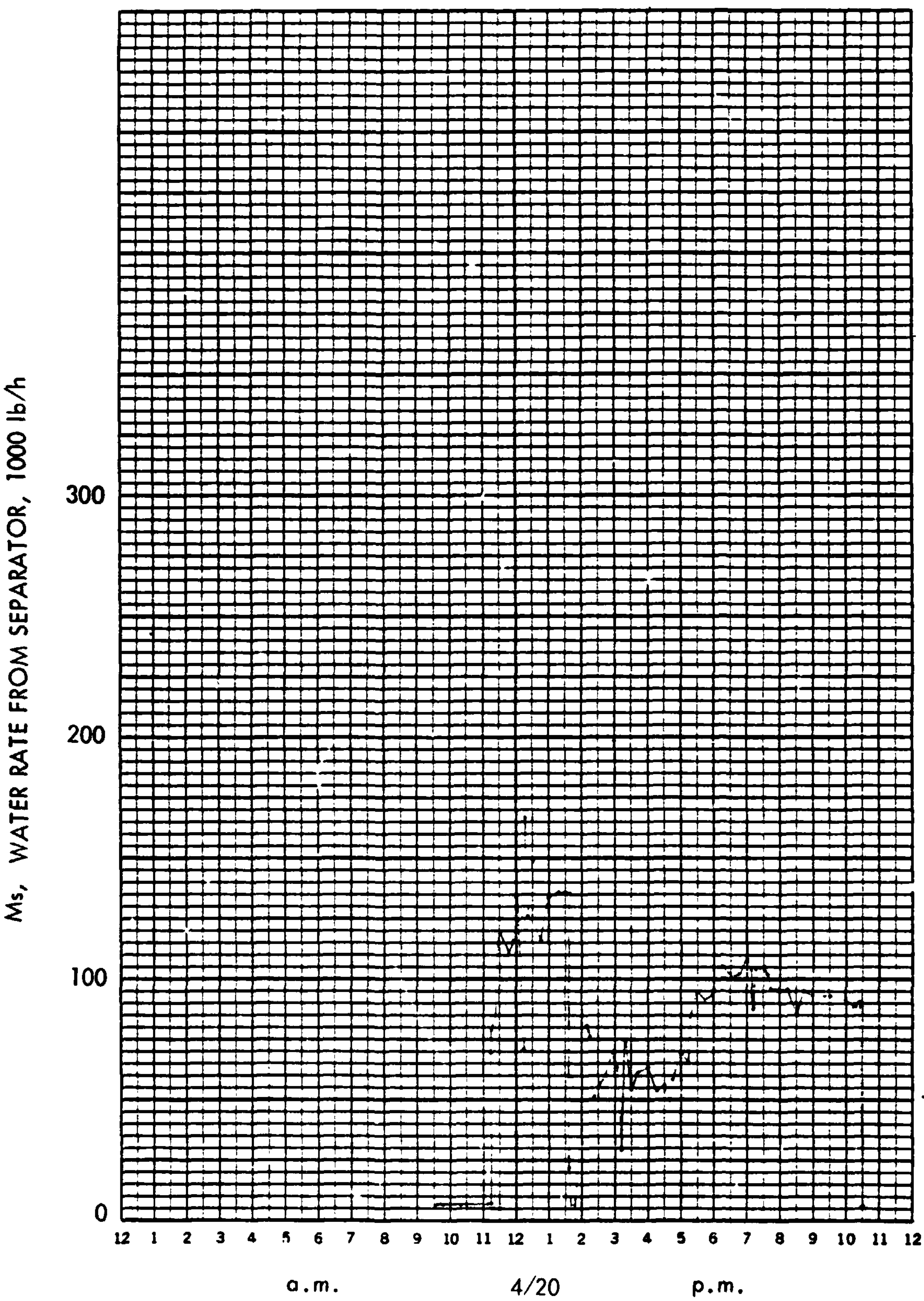

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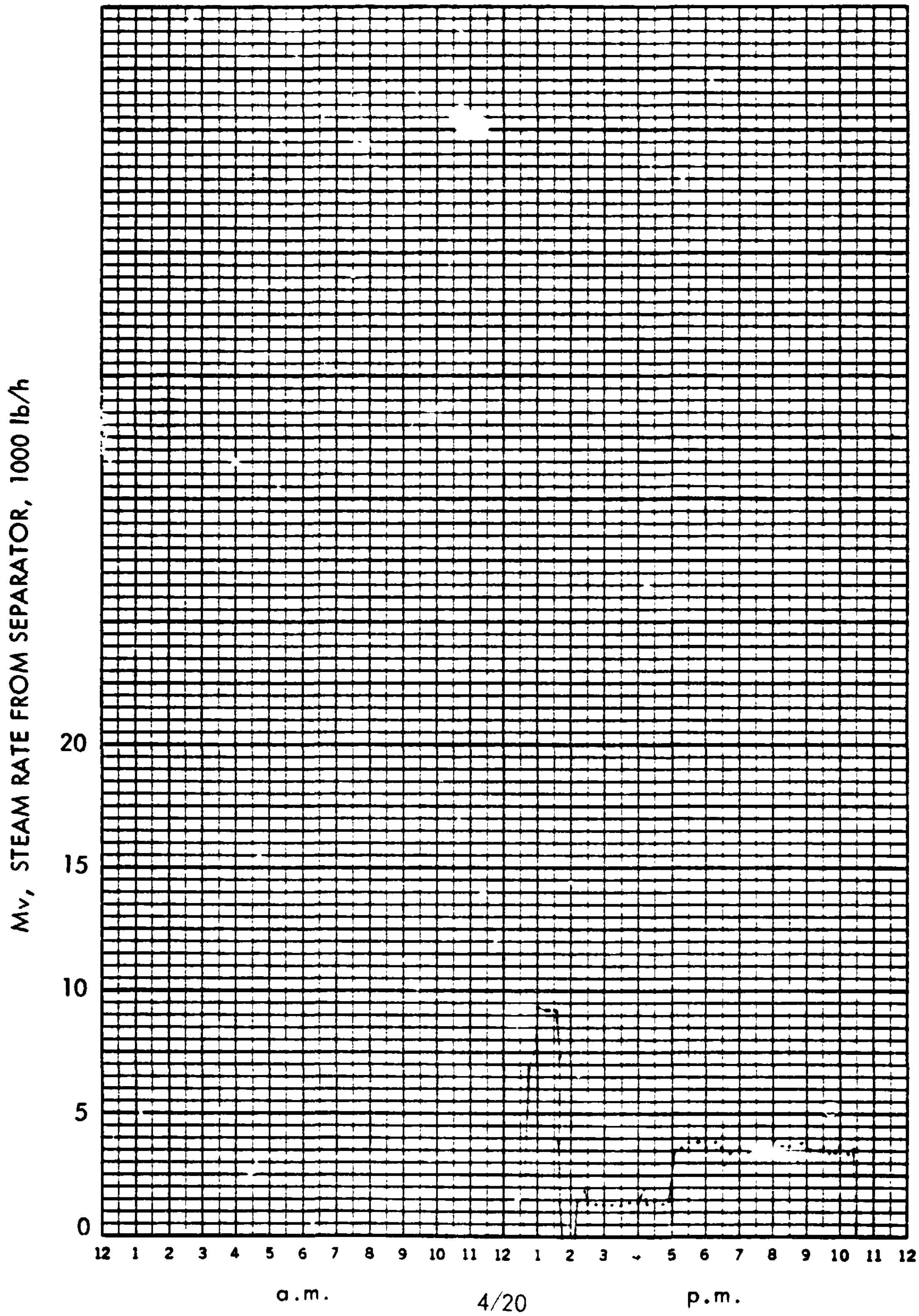

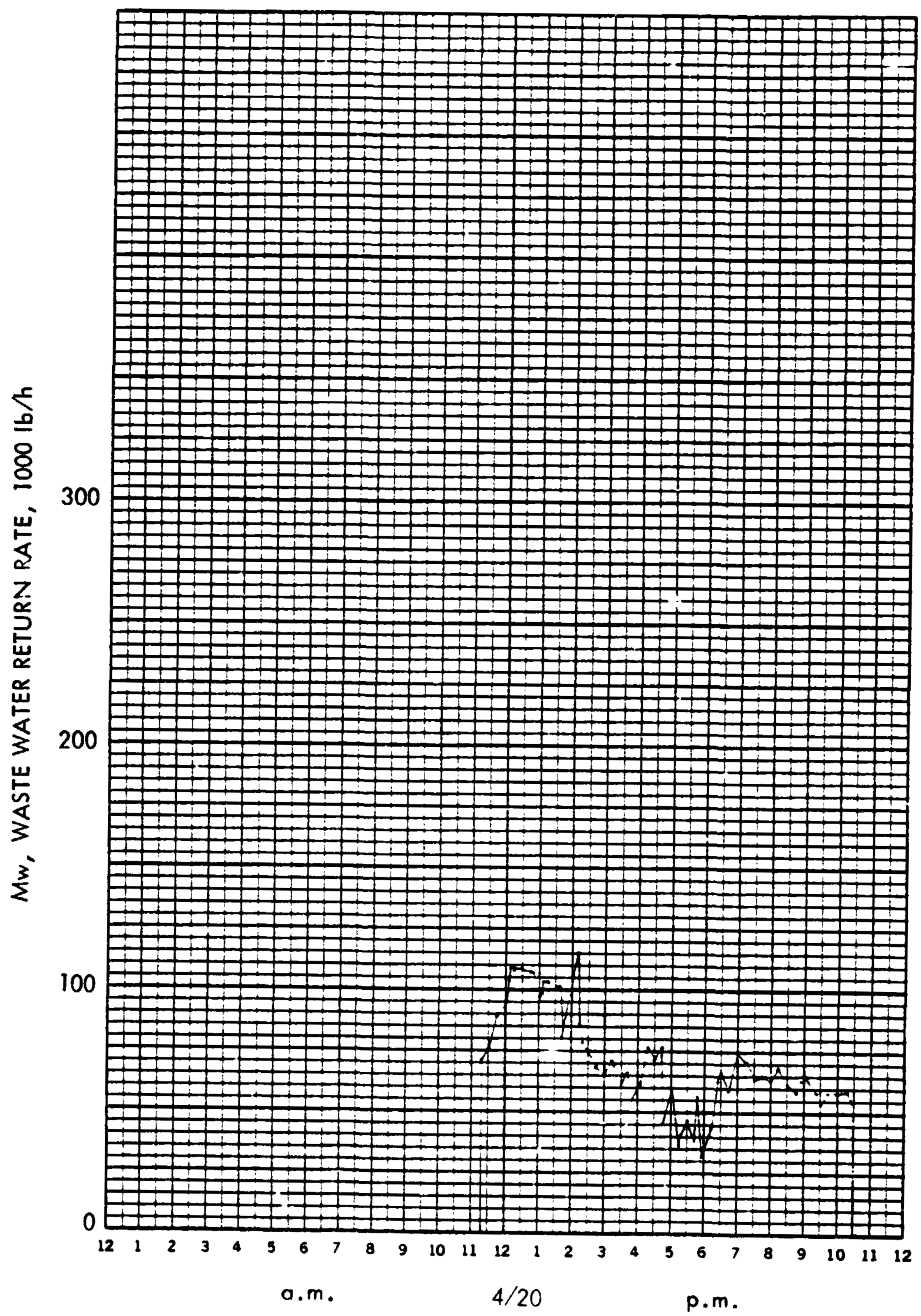
Mw, WASTE WATER RETURN RATE, 1000 lb/h
300
200
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0
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
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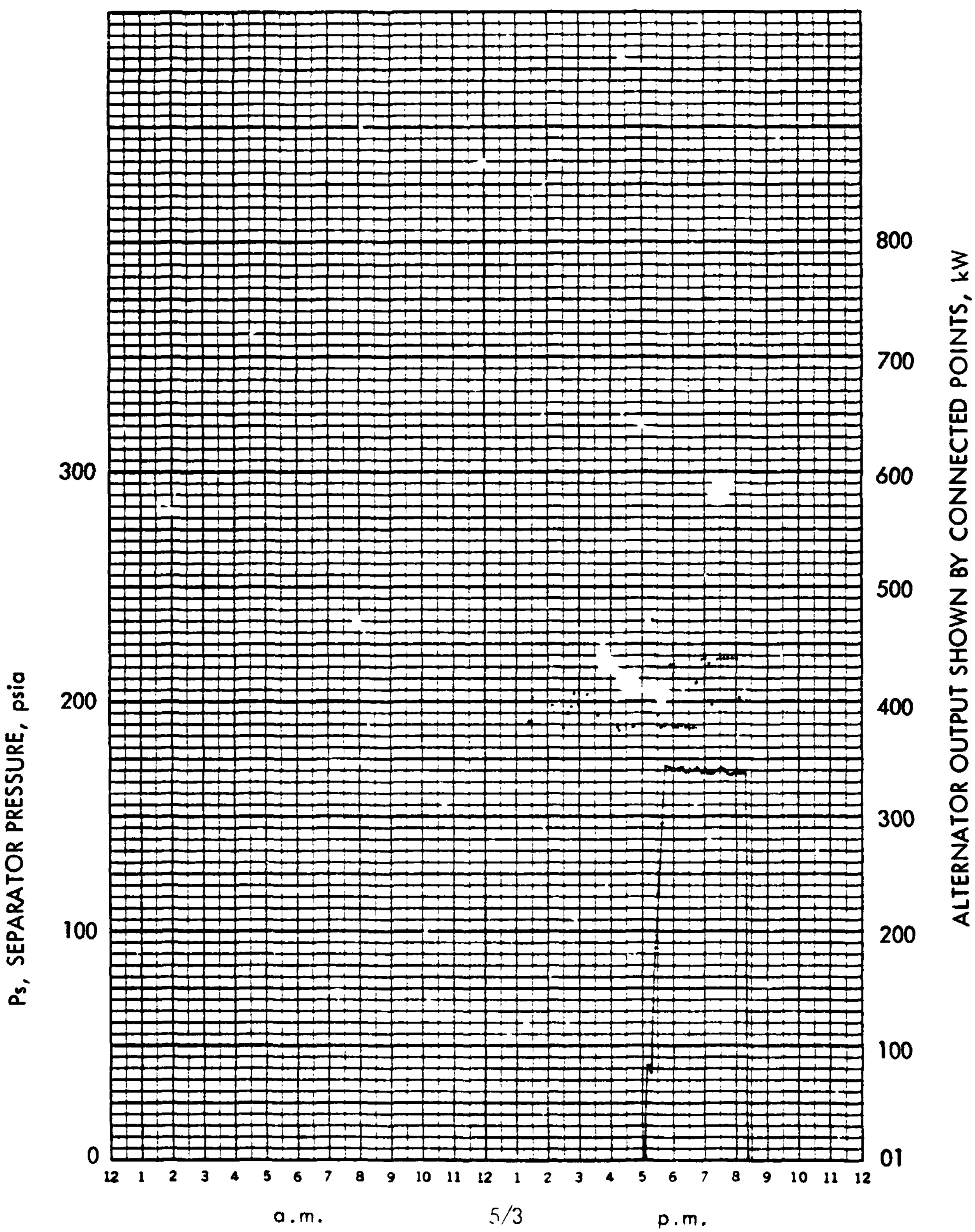

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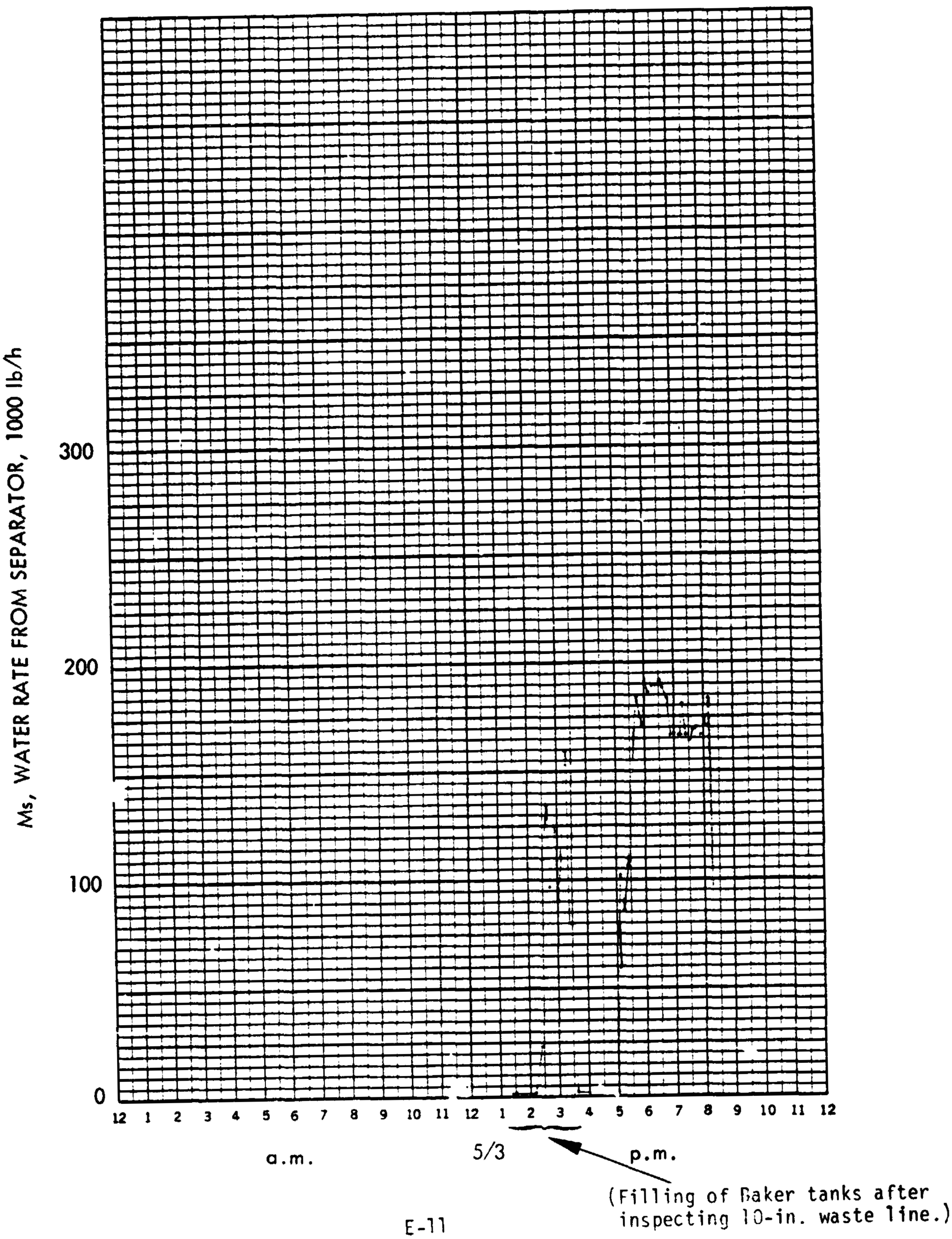

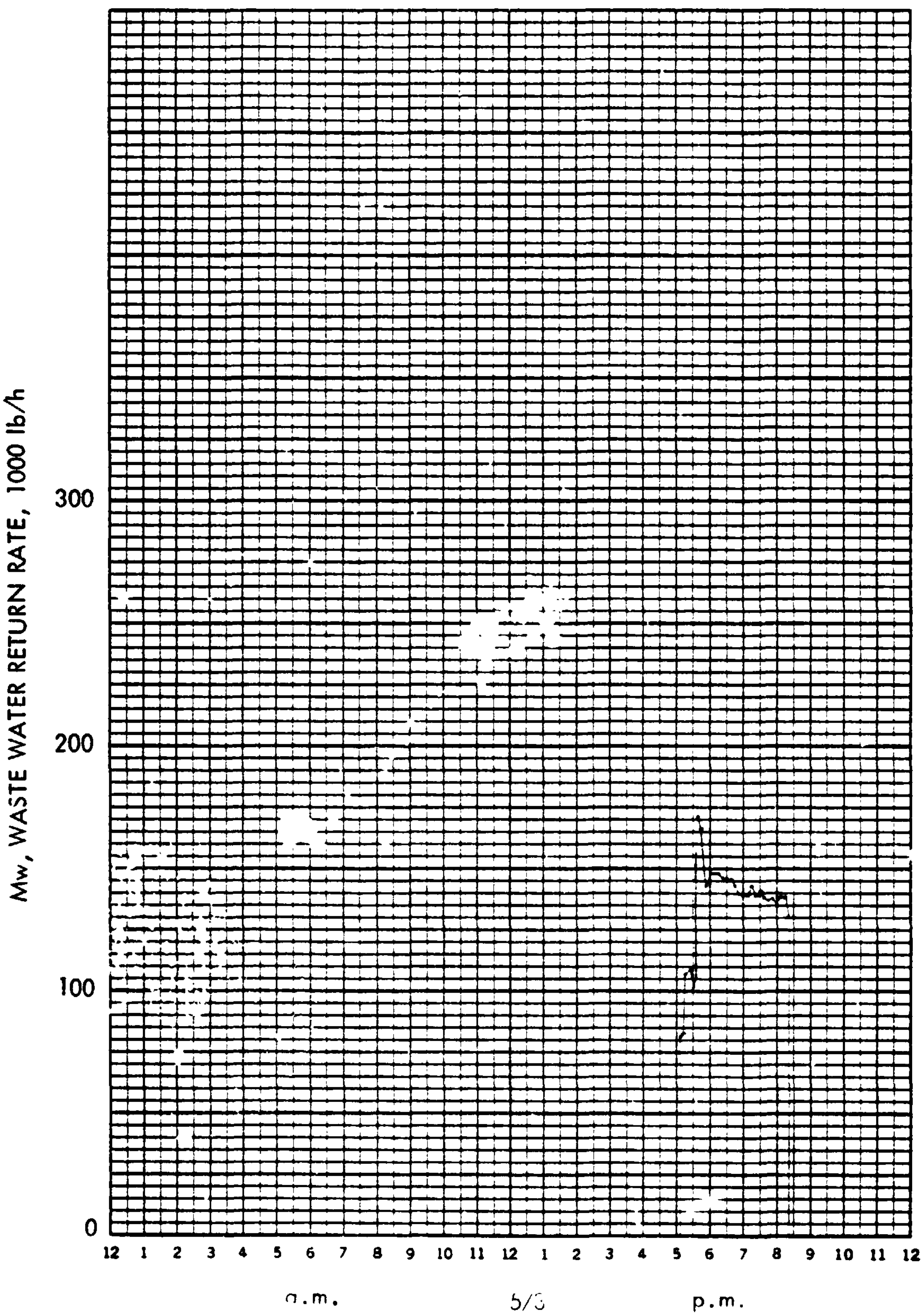
Mw, WASTE WATER RETURN RATE, 1000 lb/h
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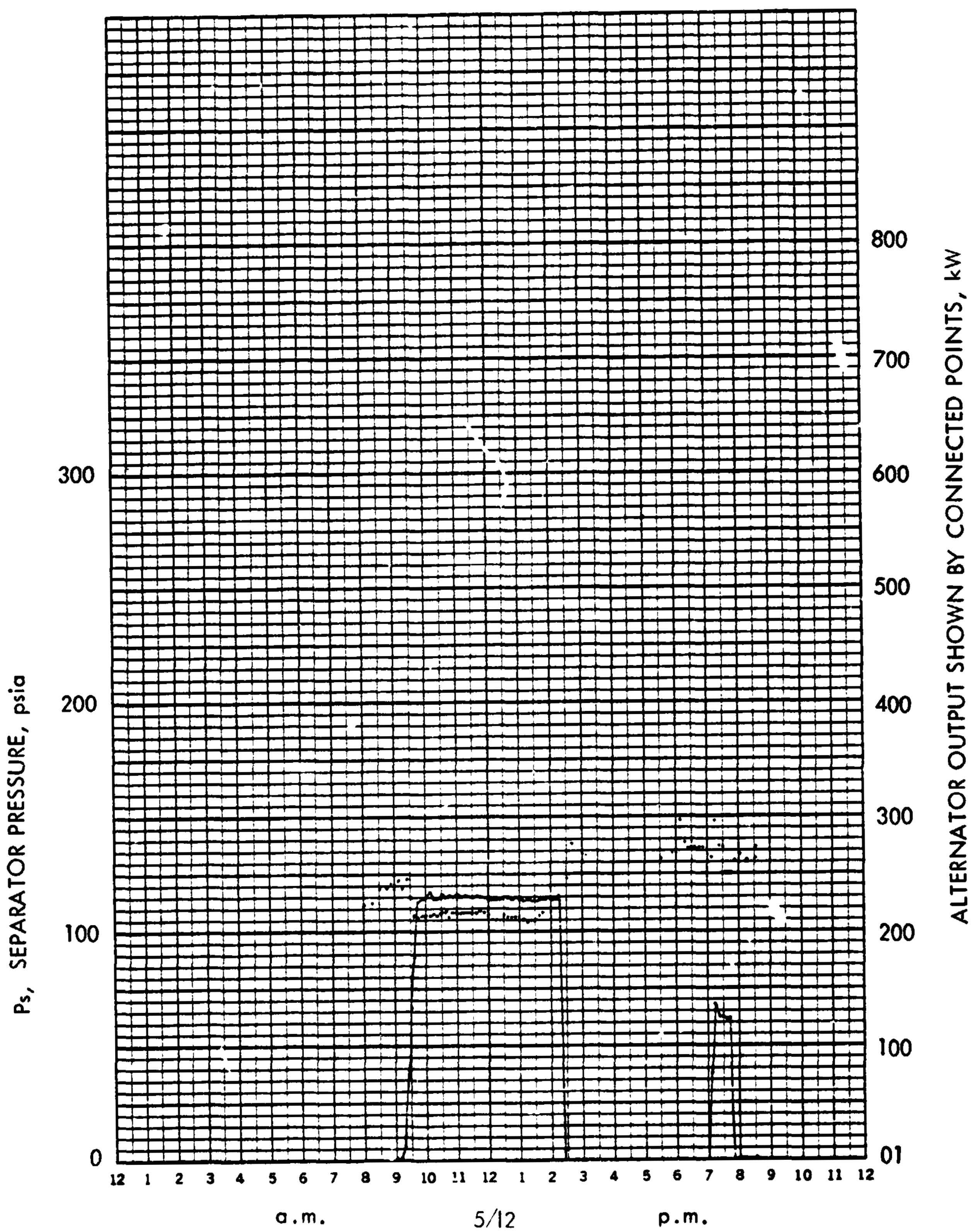
Ps, SEPARATOR PRESSURE, psia
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ALTERNATOR OUTPUT SHOWN BY CONNECTED POINTS, kW
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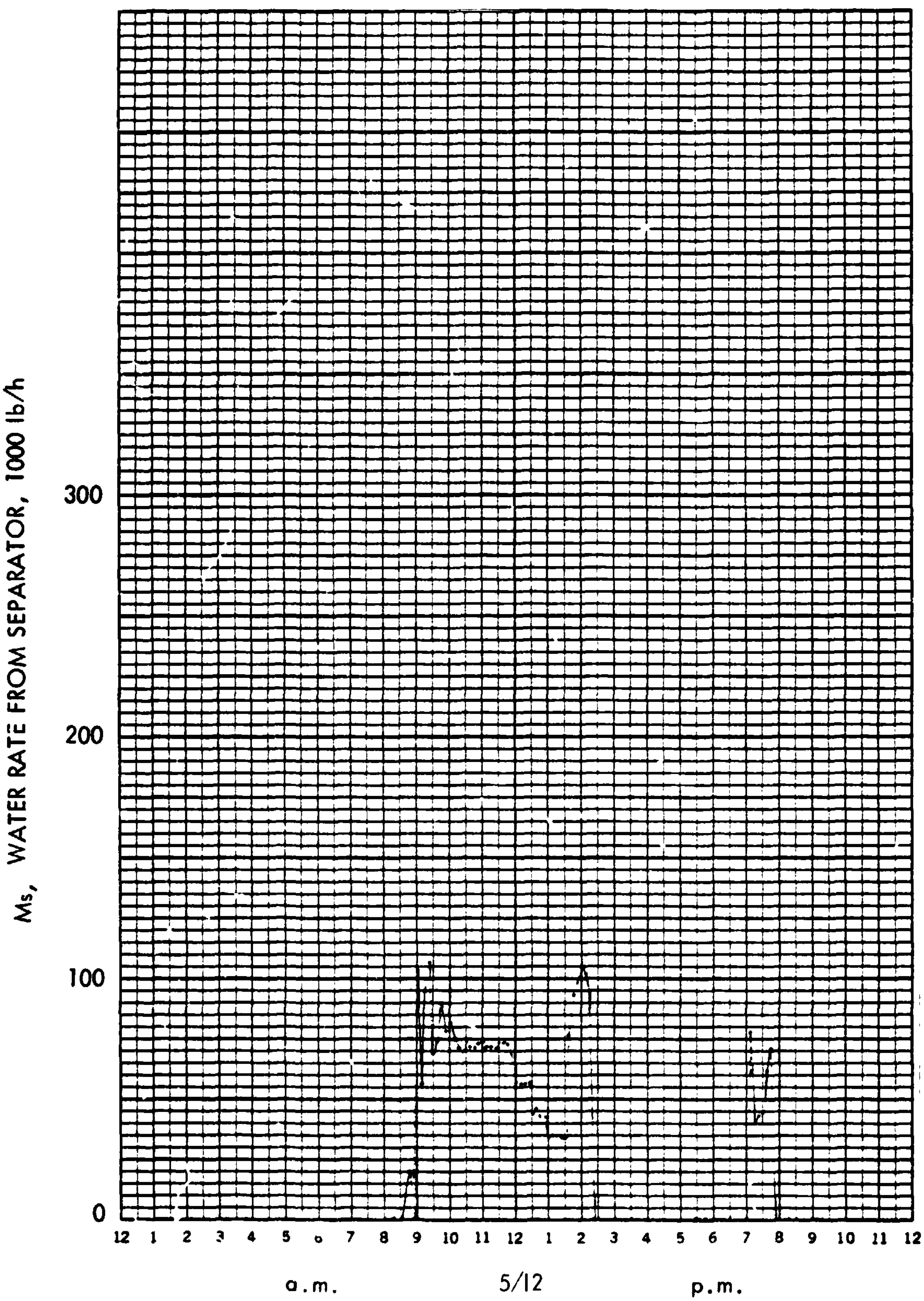
Ms, WATER RATE FROM SEPARATOR, 1000 lb/h
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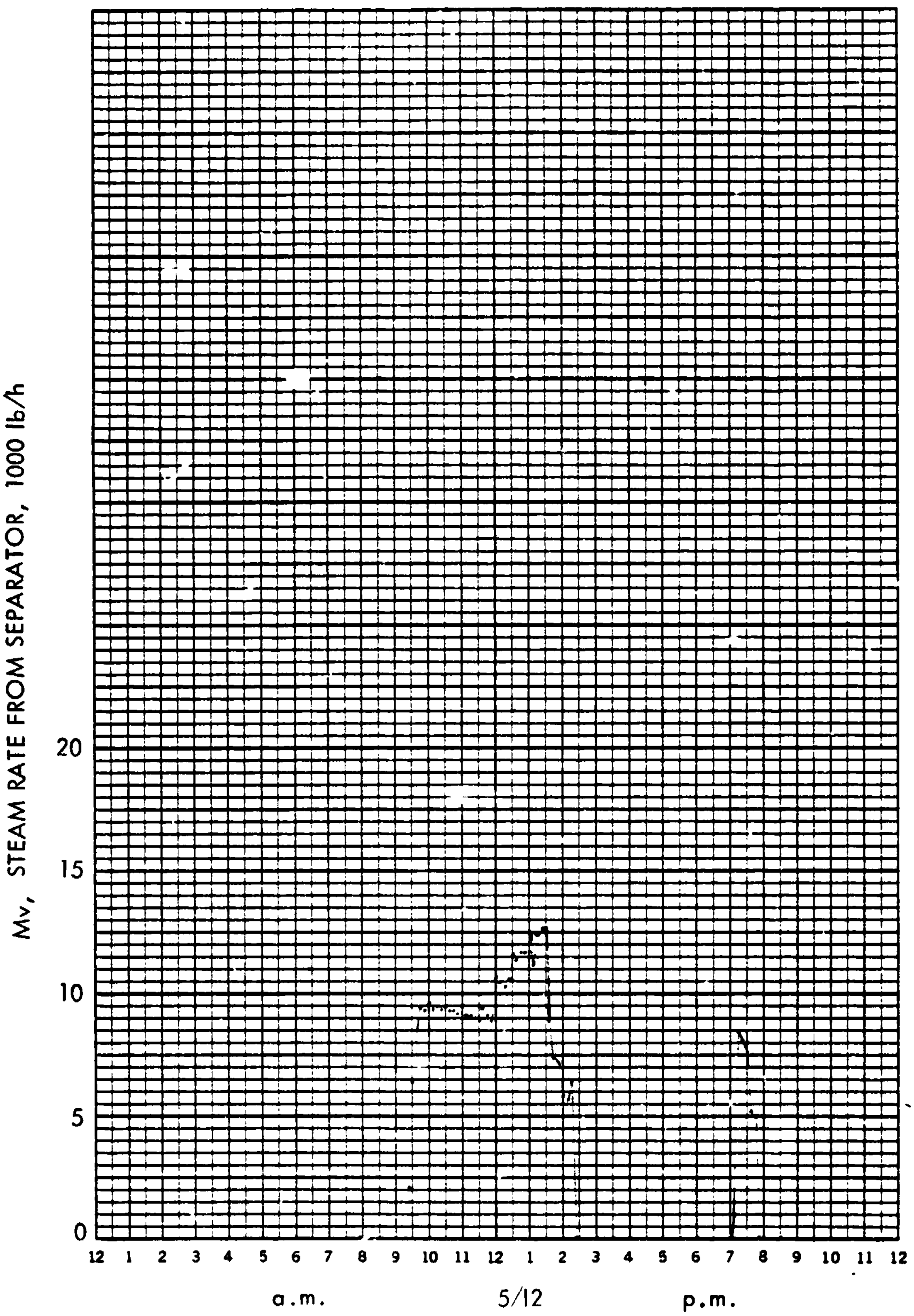

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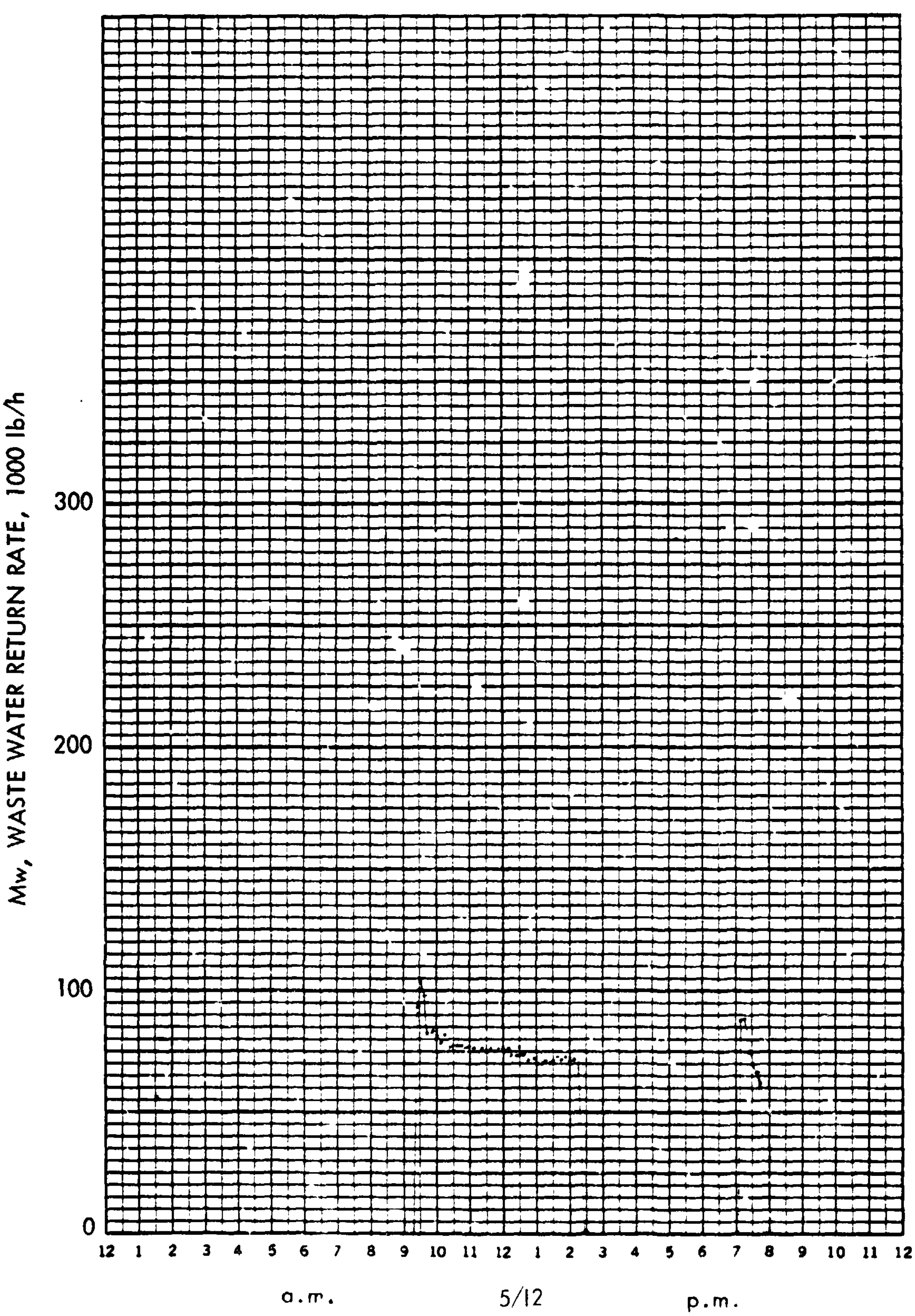

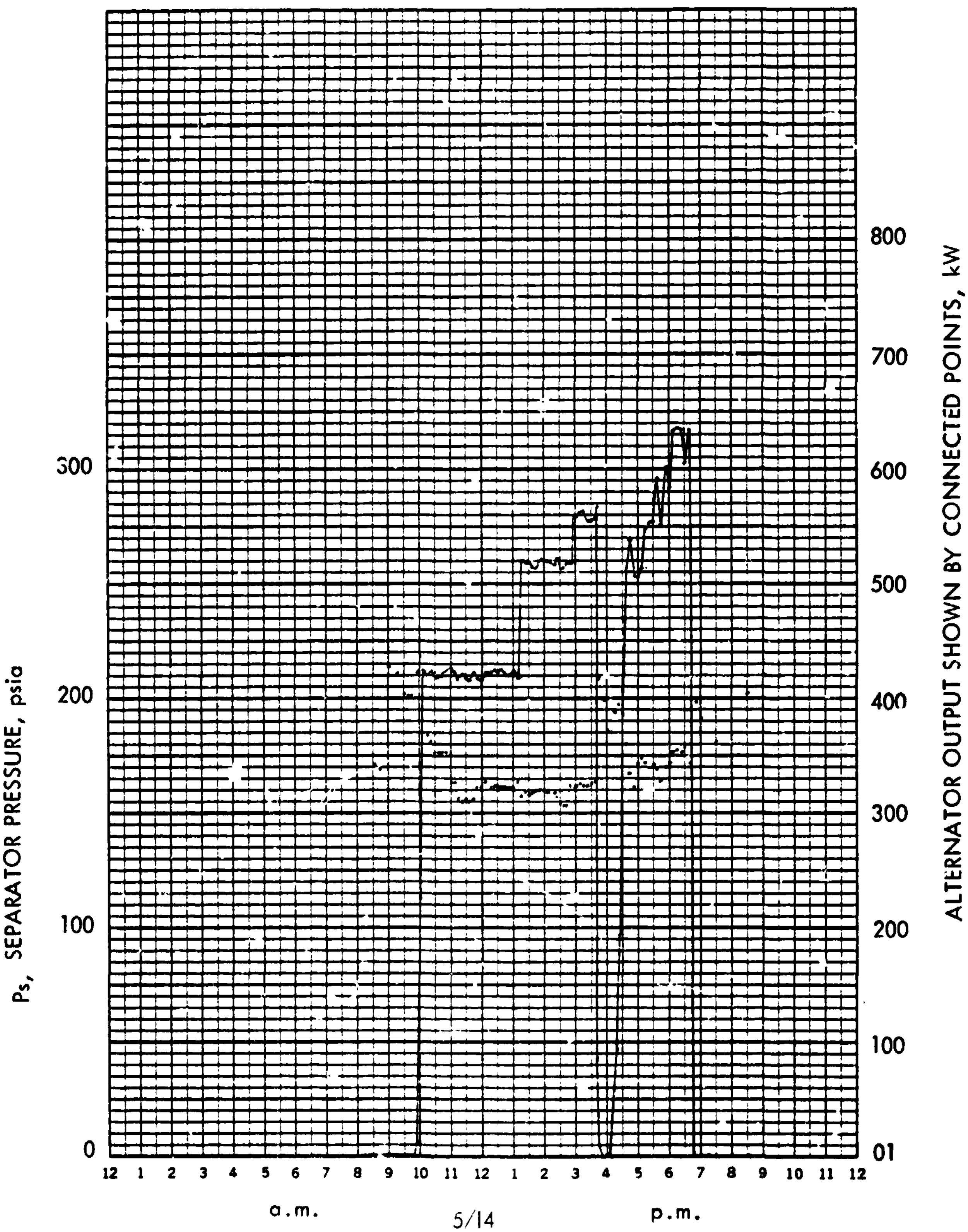
Ps, SEPARATOR PRESSURE, psia
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ALTERNATOR OUTPUT SHOWN BY CONNECTED POINTS, kW
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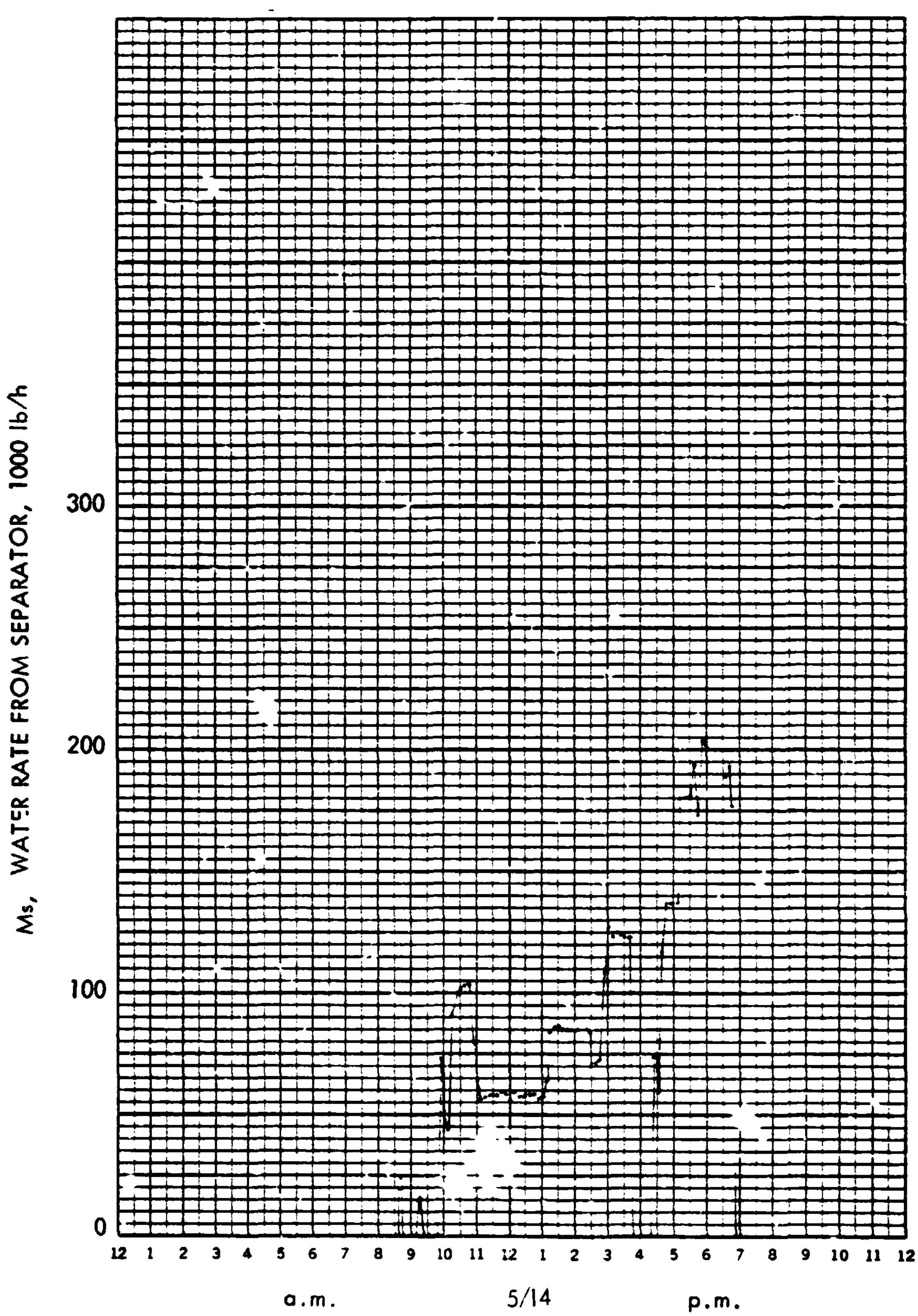
Ms, WATER RATE FROM SEPARATOR, 1000 lb/h
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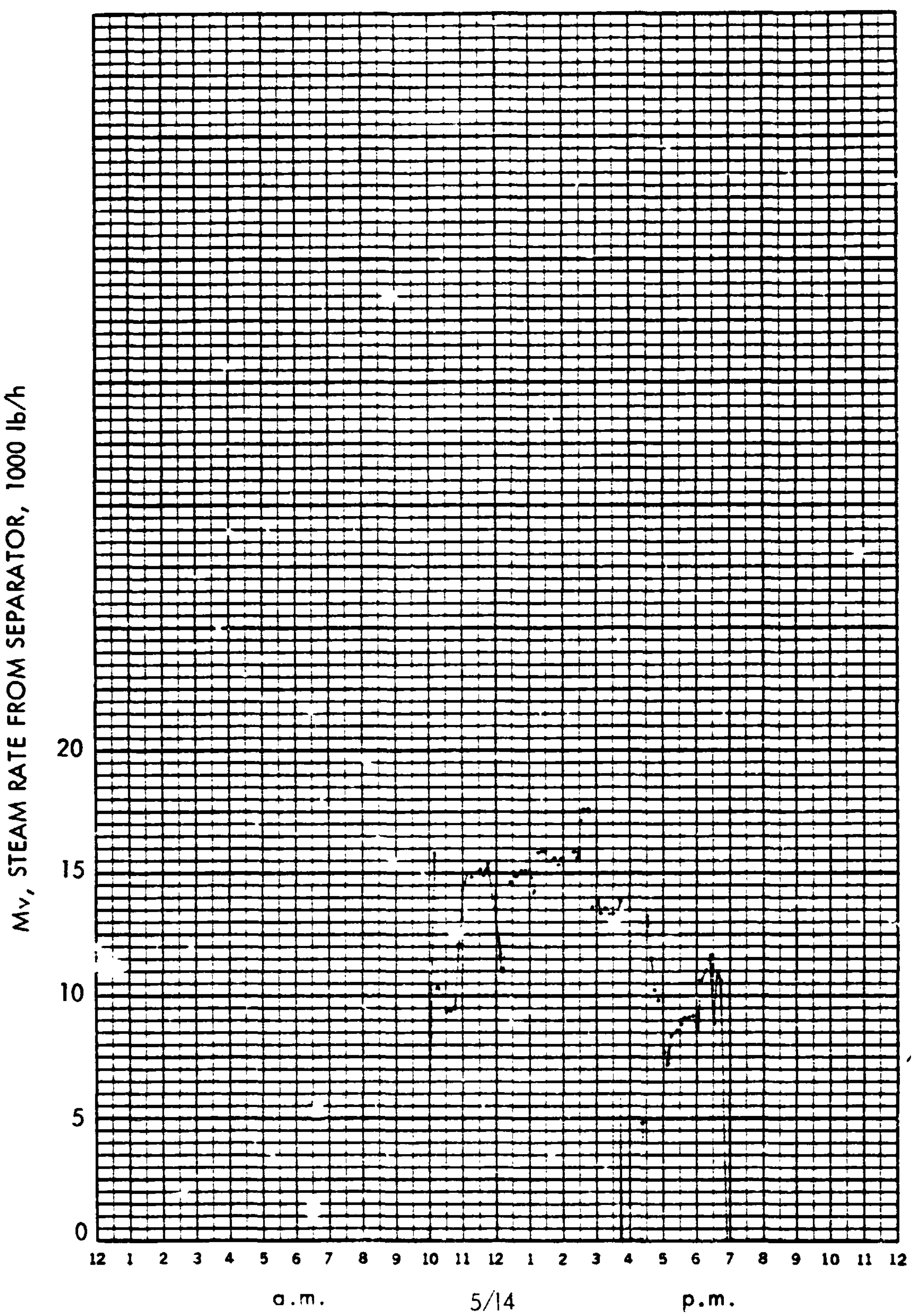
Mv, STEAM RATE FROM SEPARATOR, 1000 lb/h
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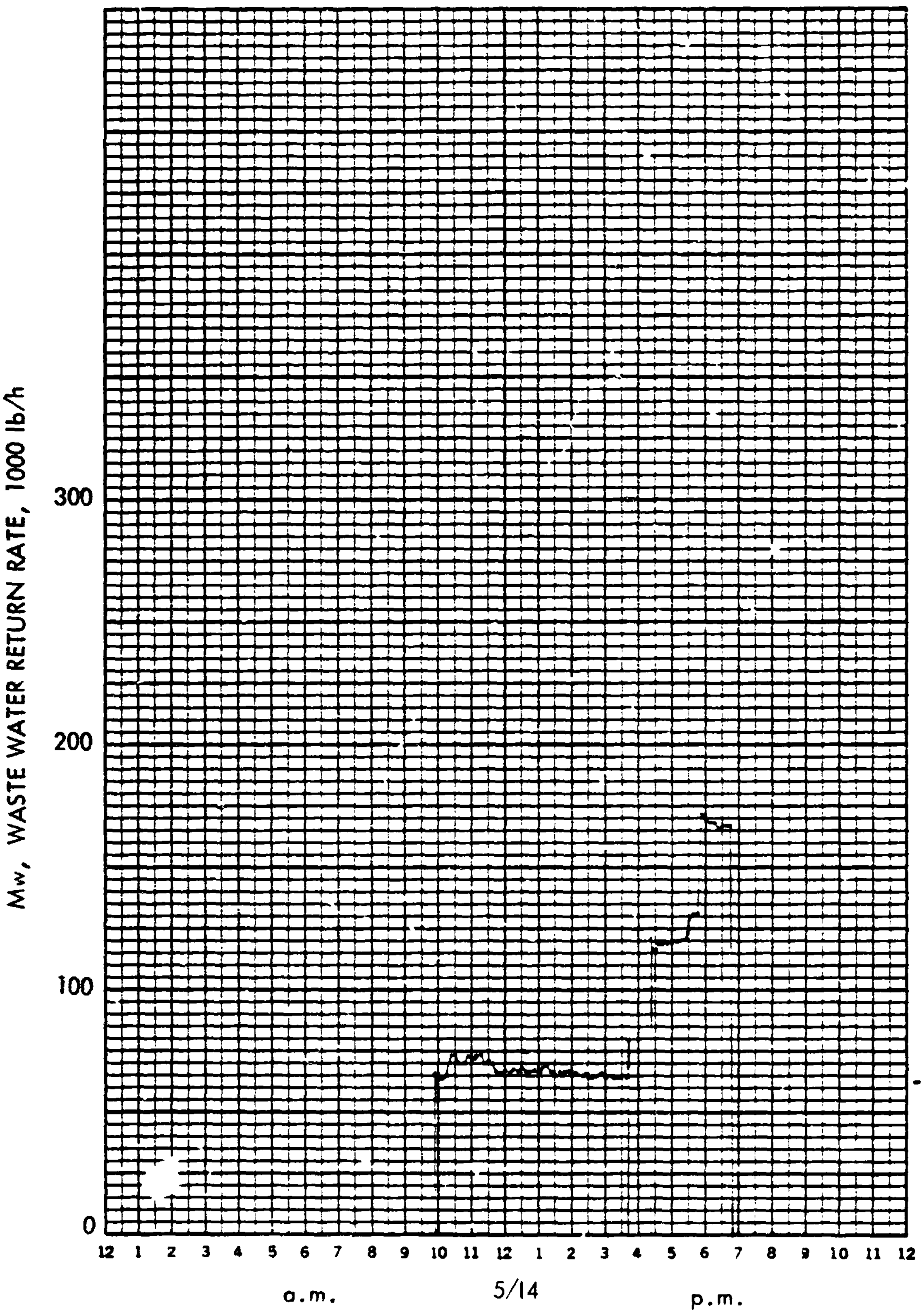

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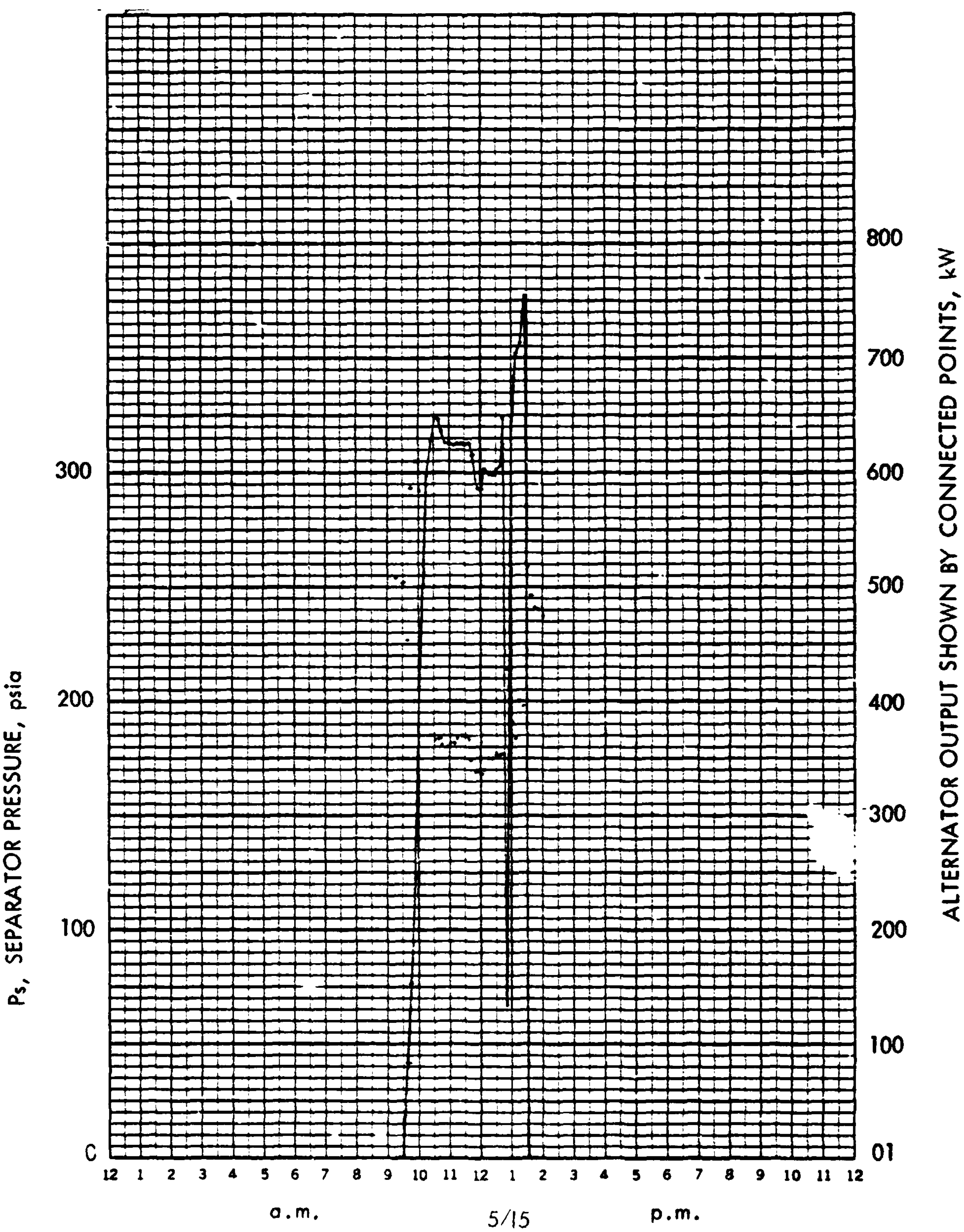

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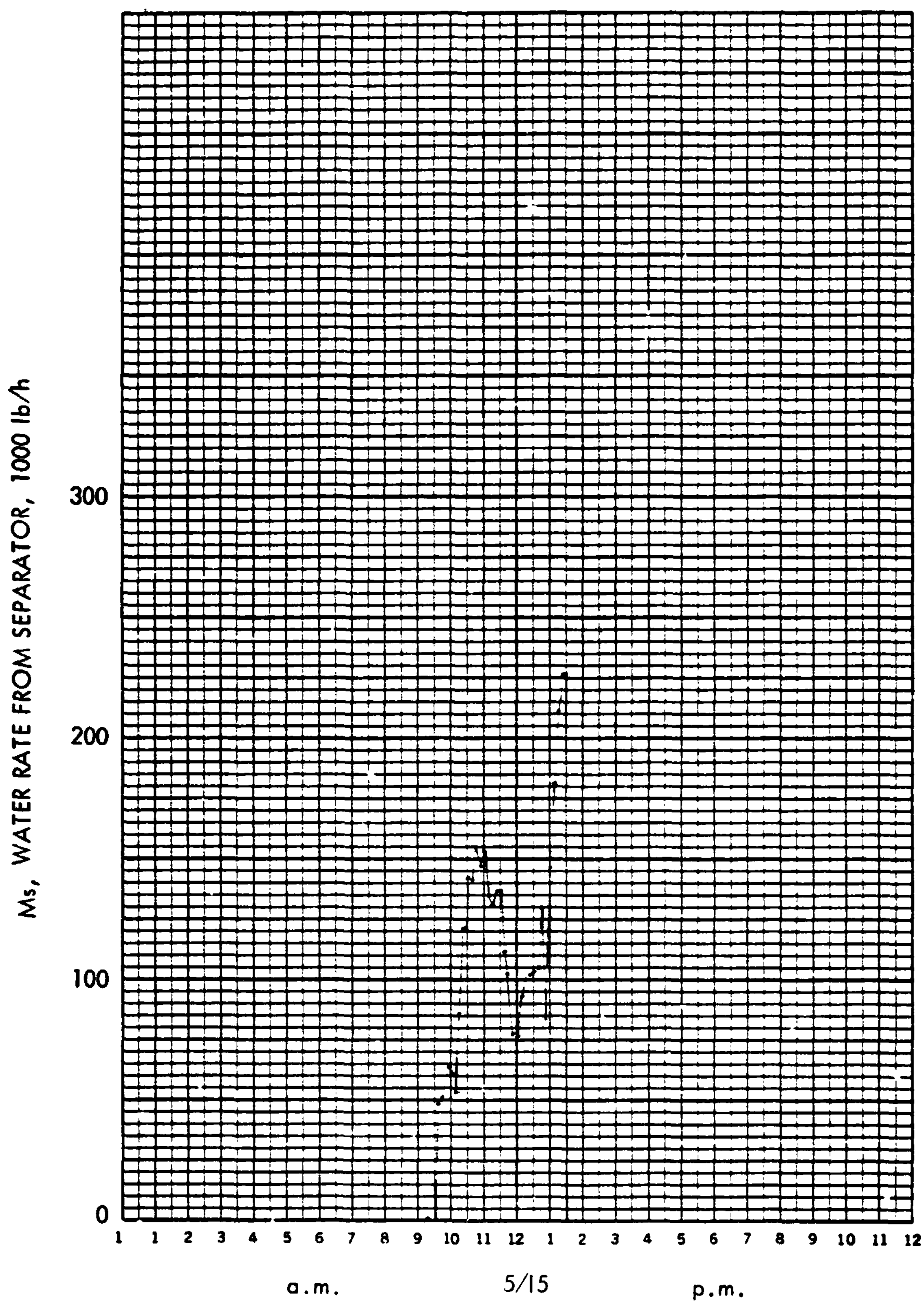

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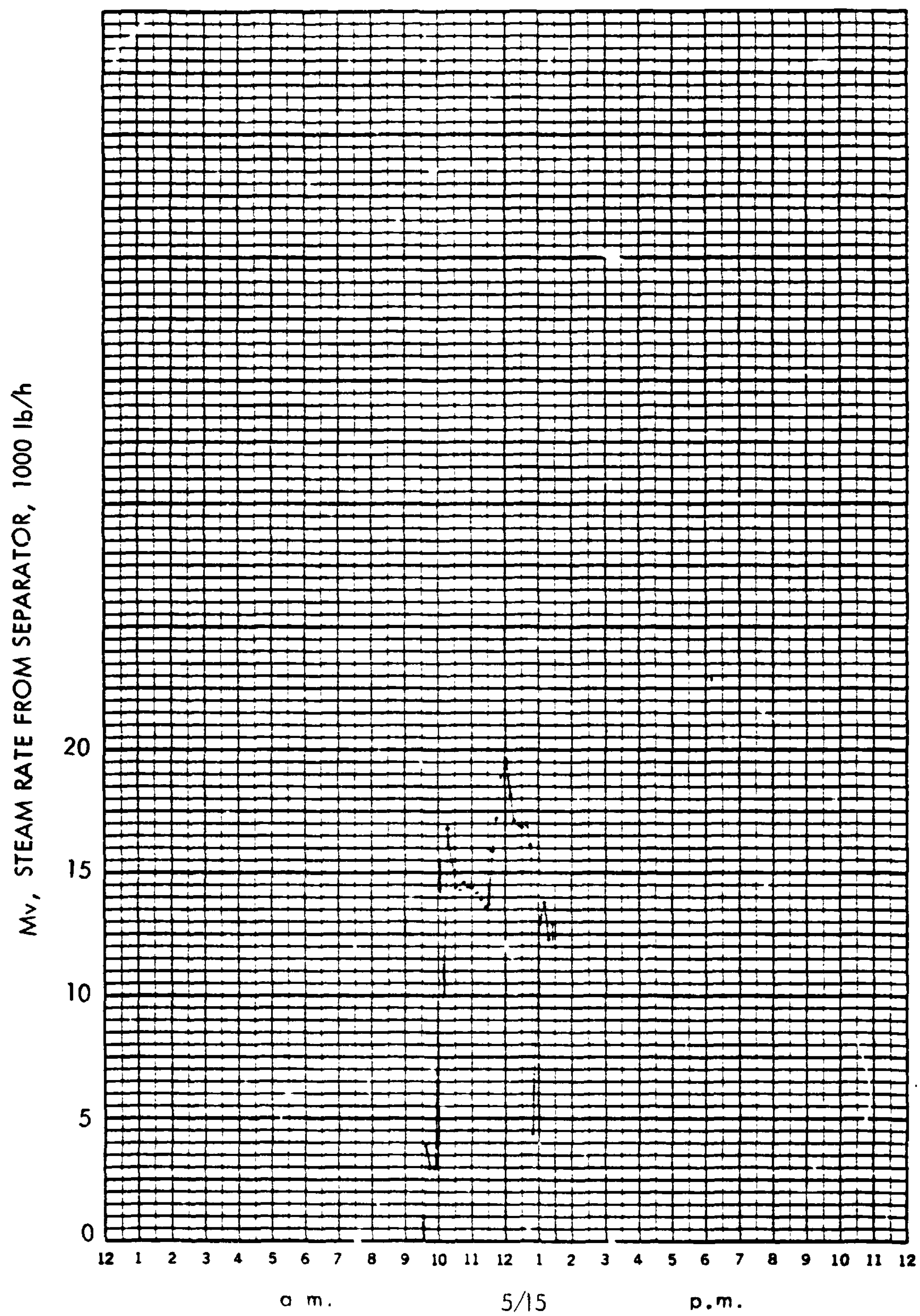

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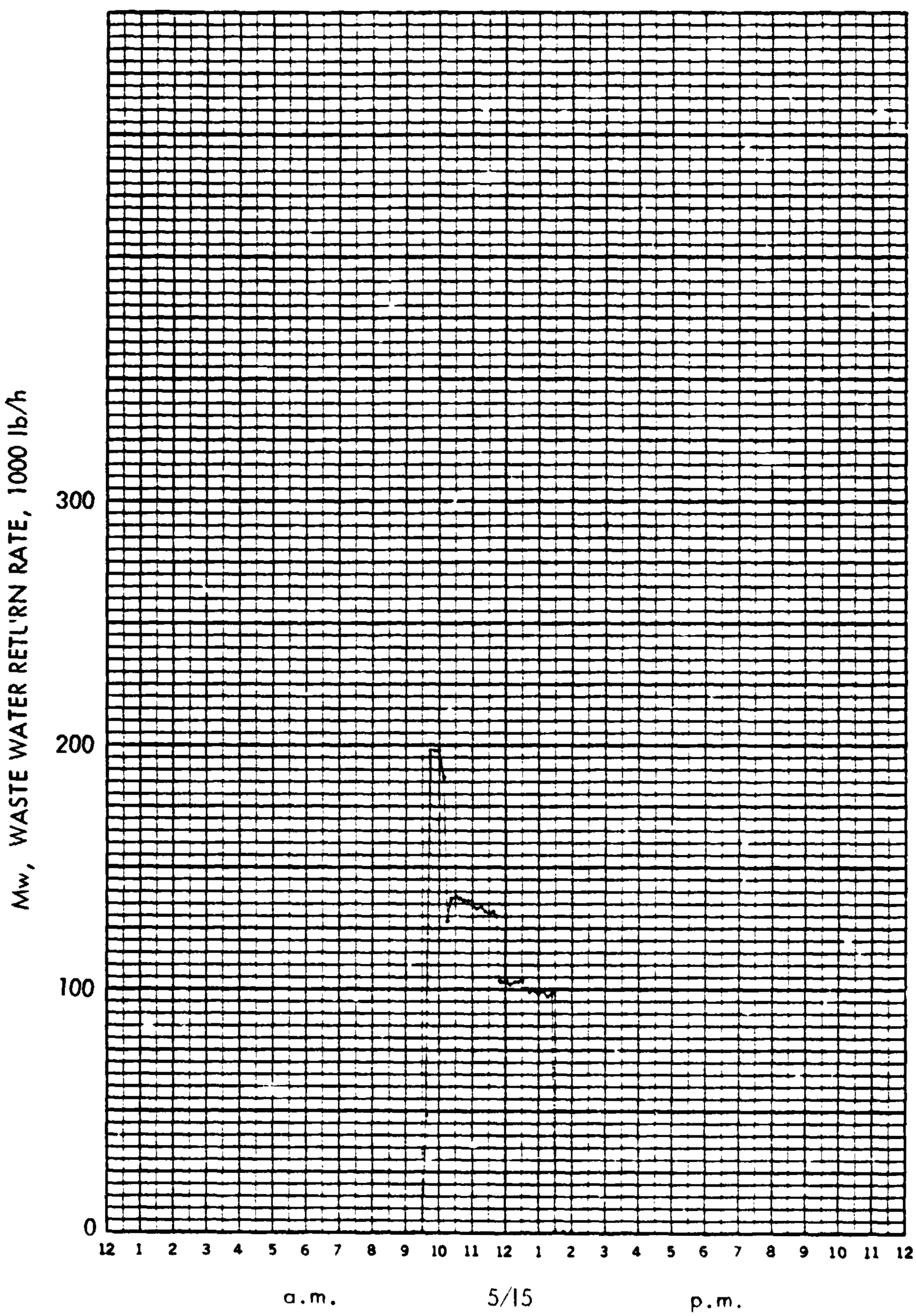

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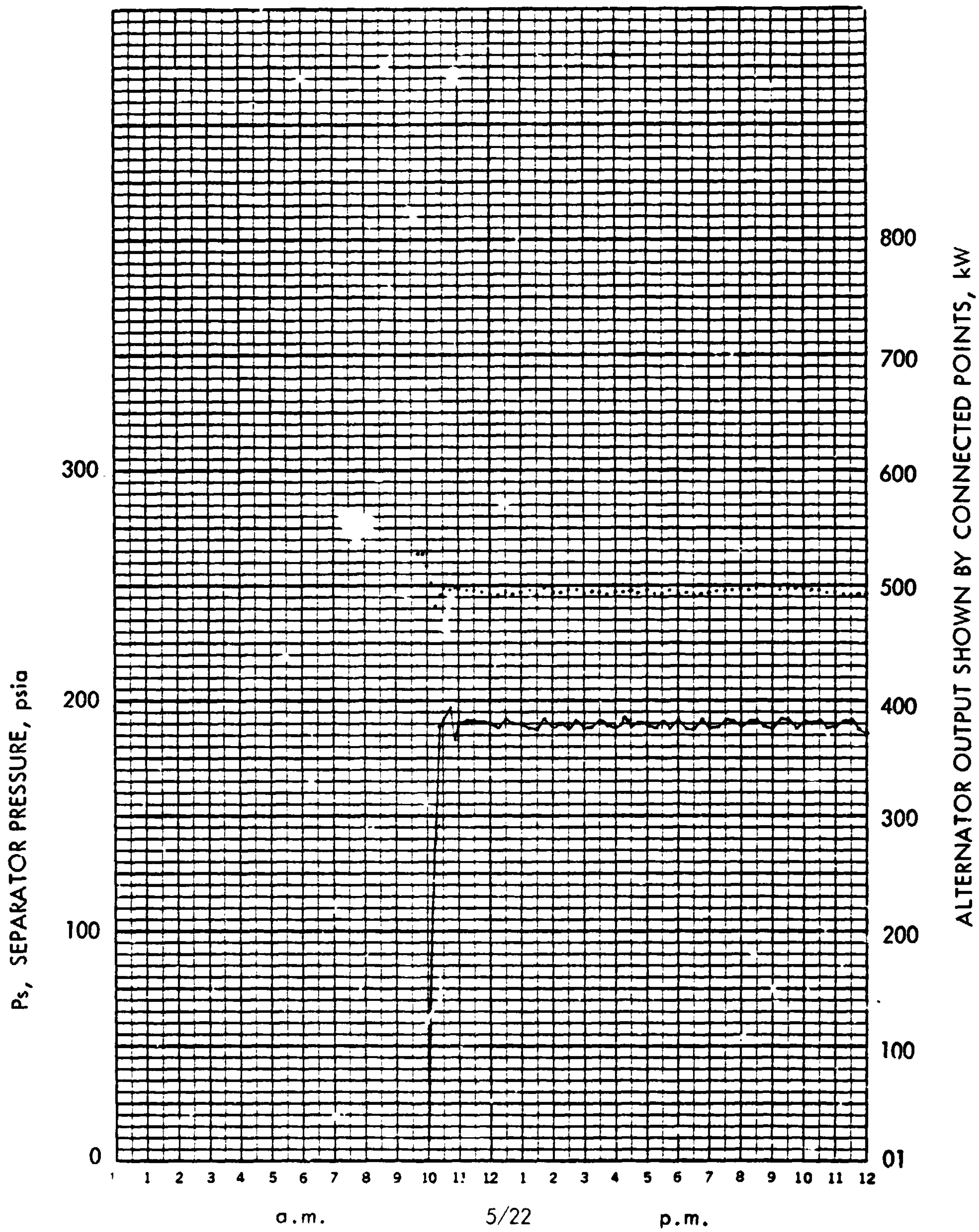

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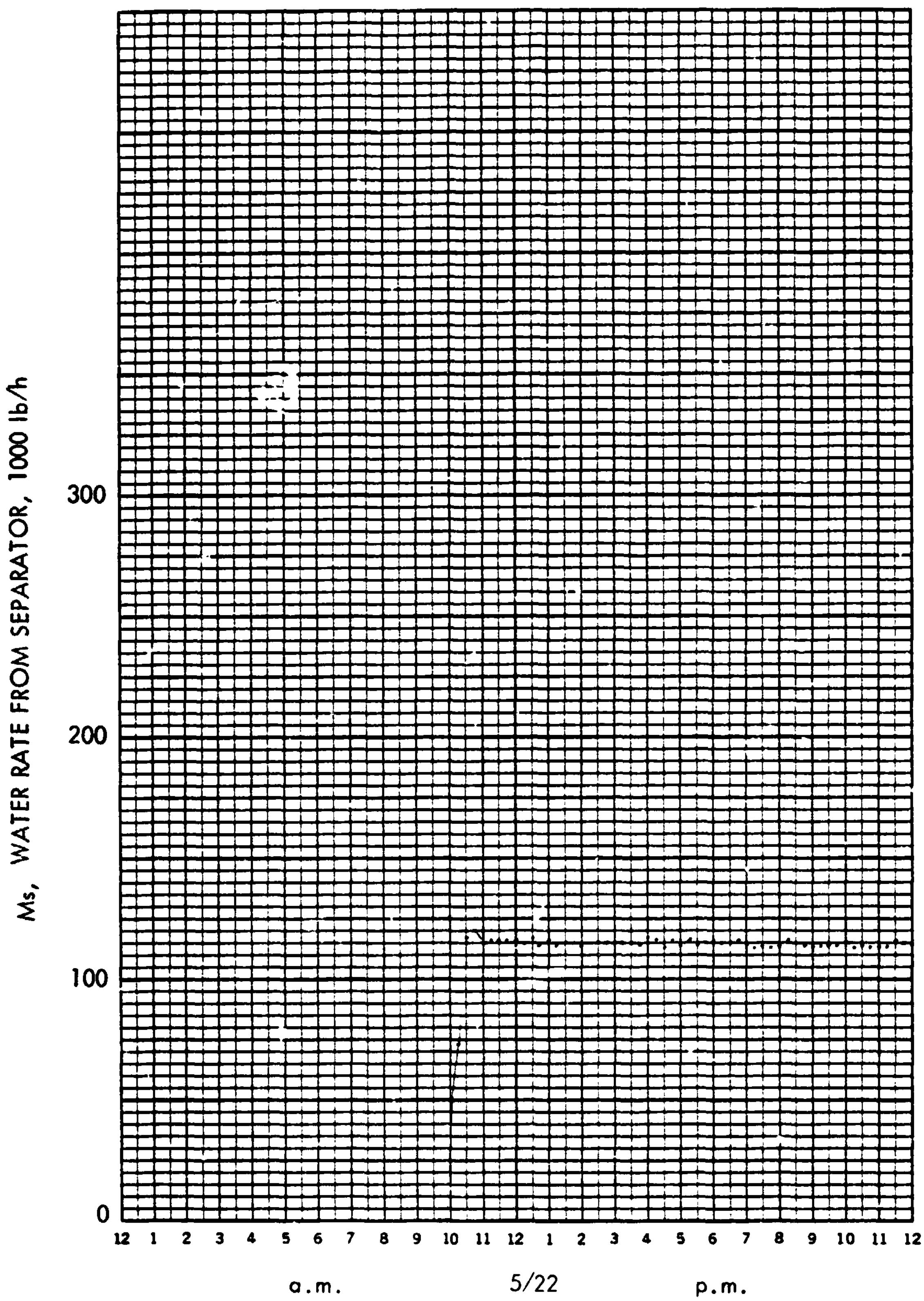

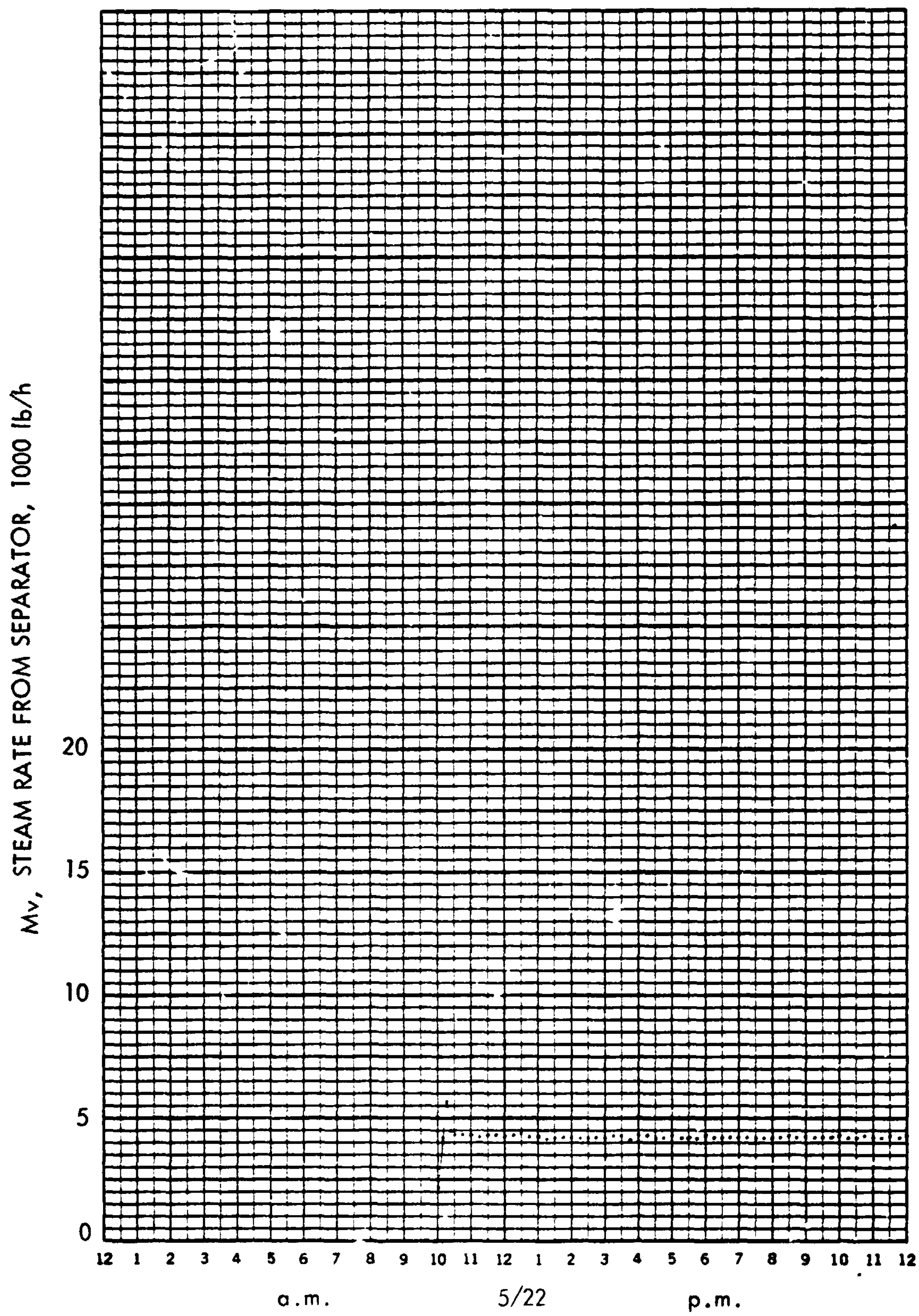
Mv, STEAM RATE FROM SEPARATOR, 1000 lb/h
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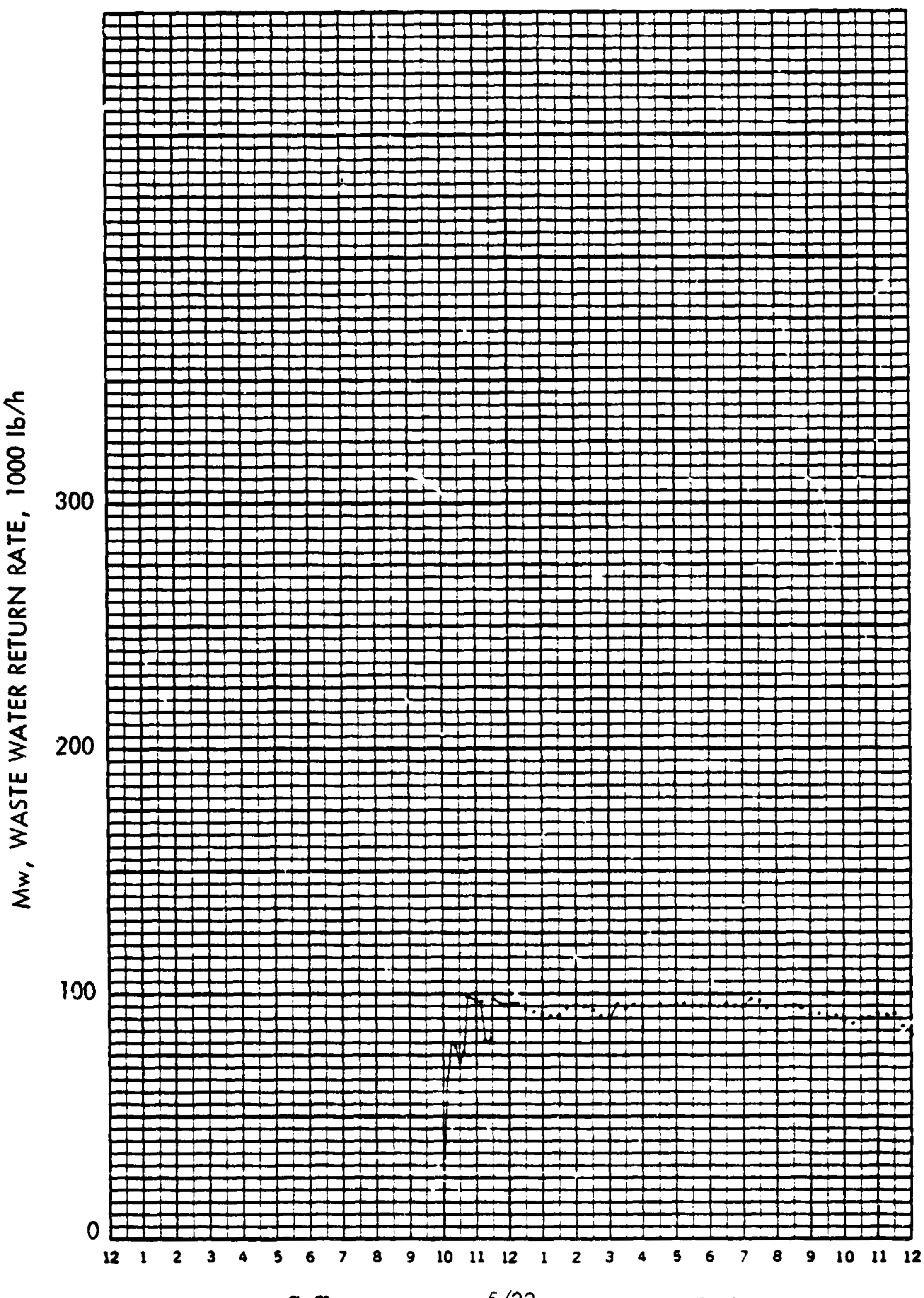

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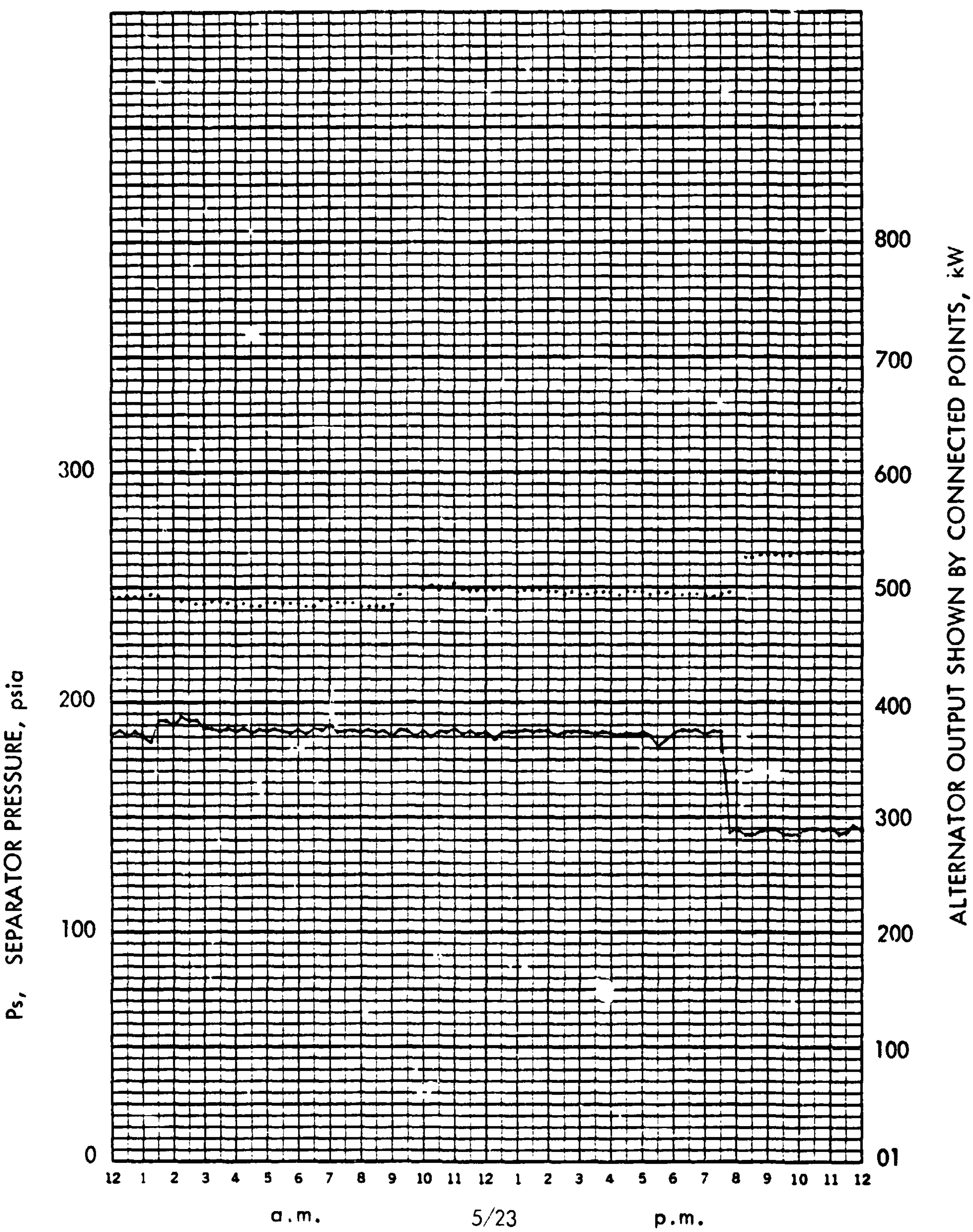

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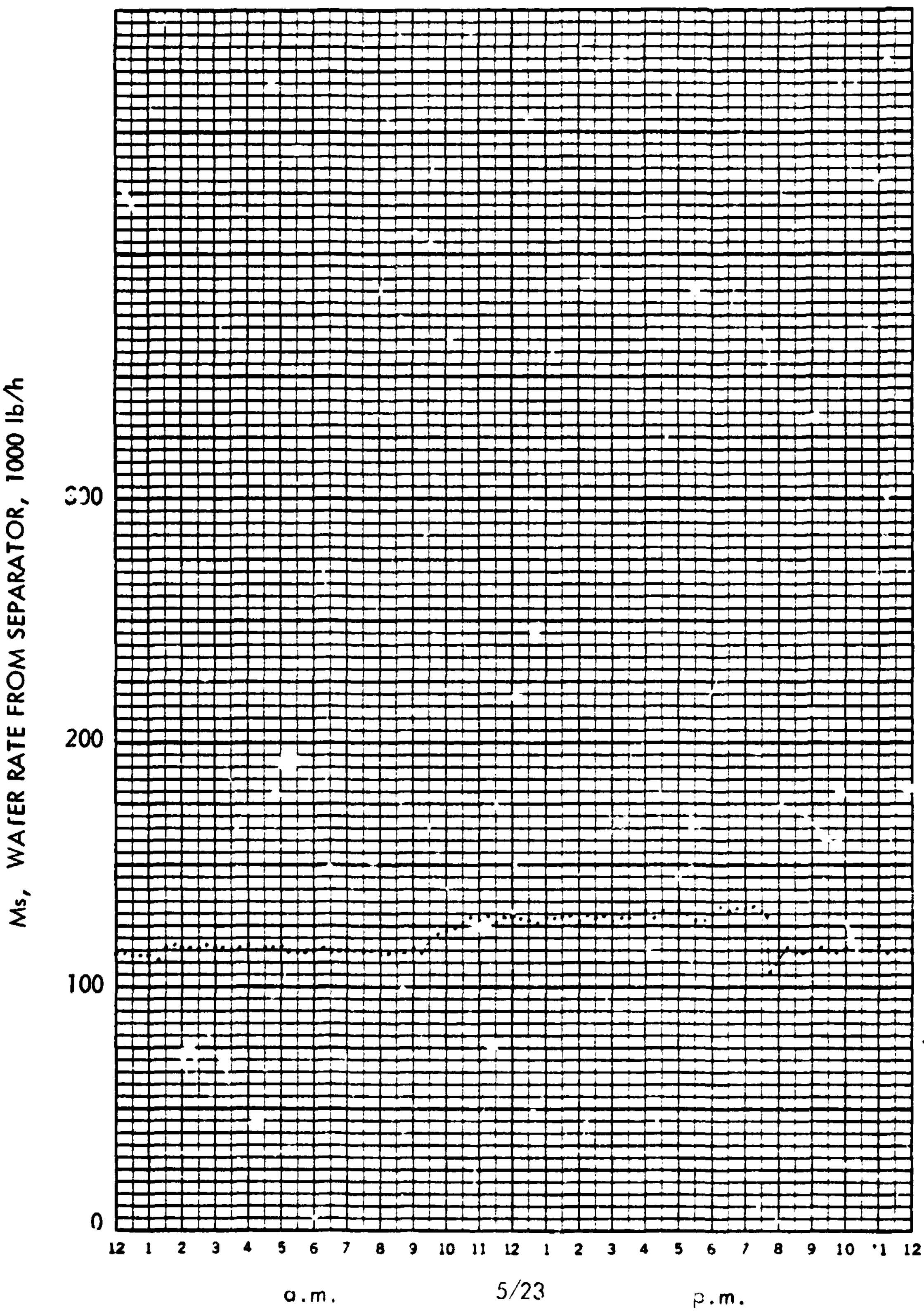

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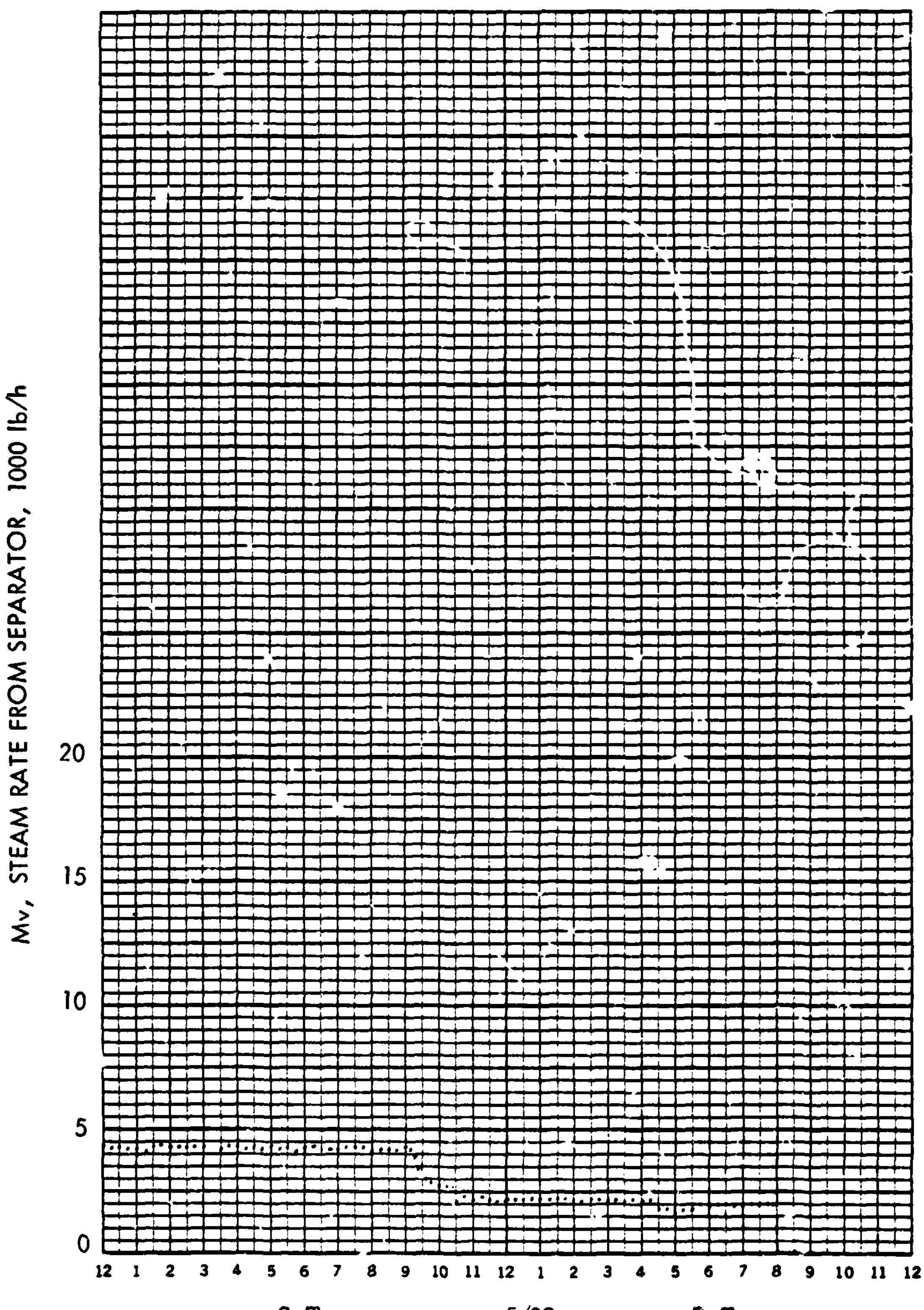

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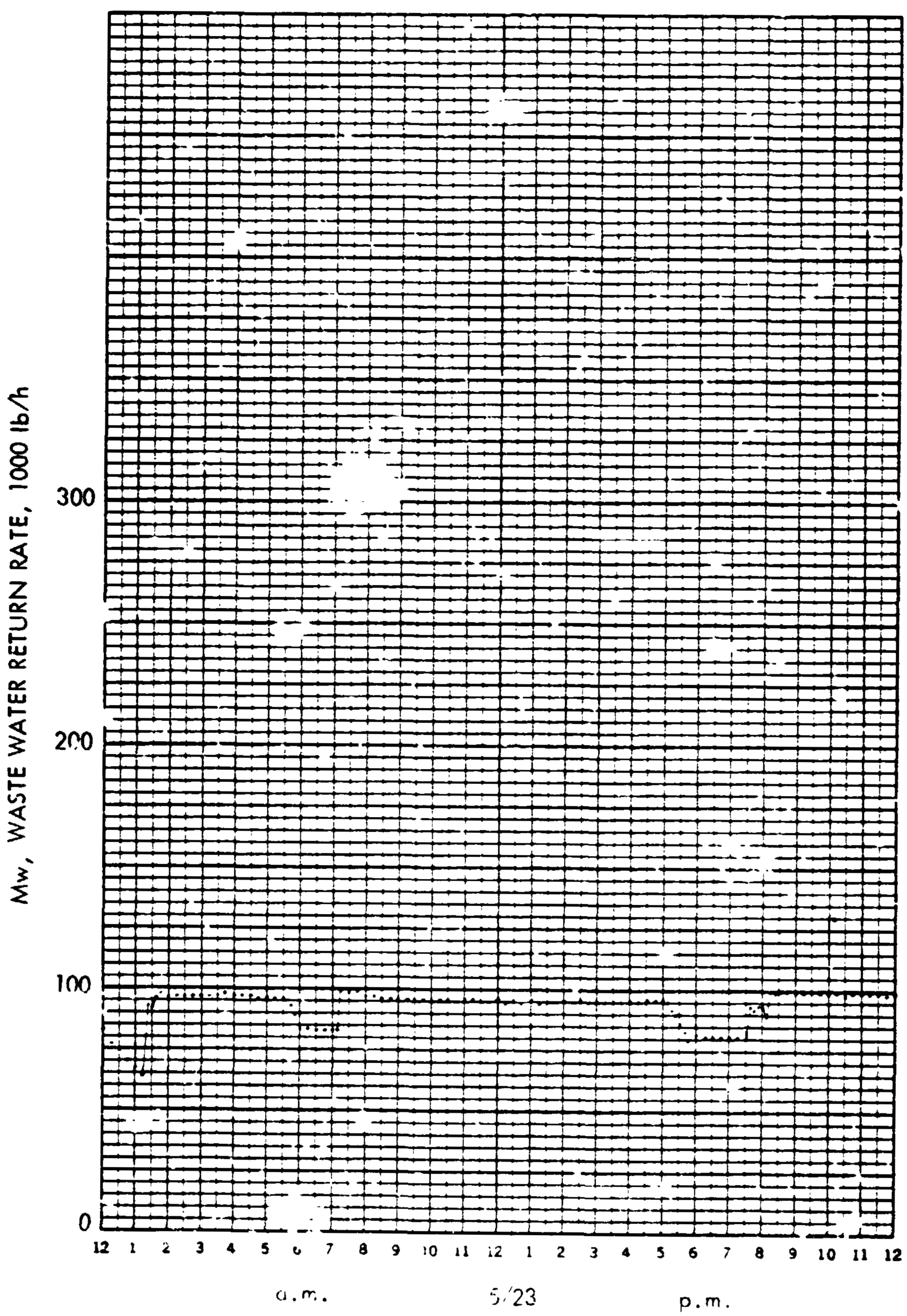

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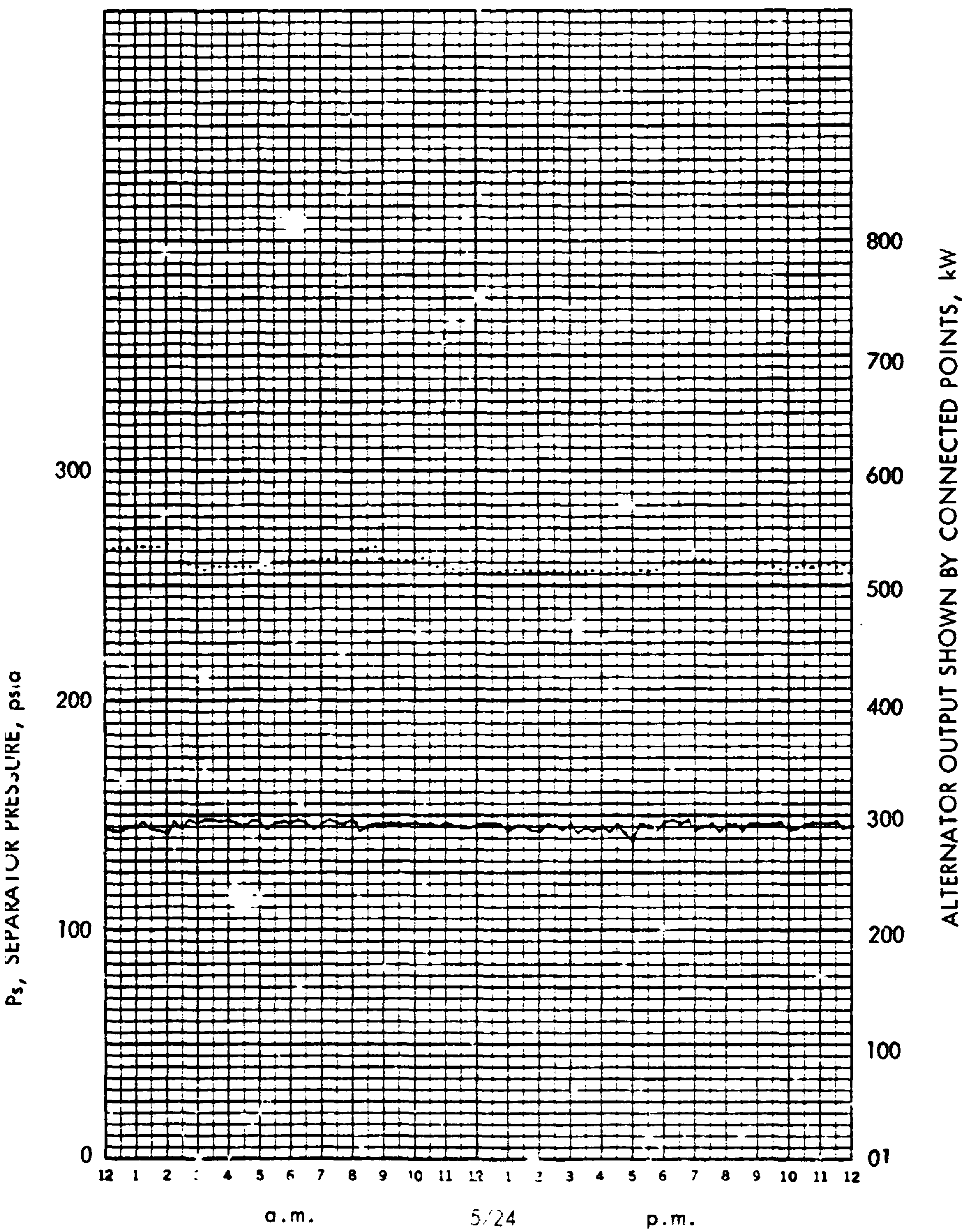

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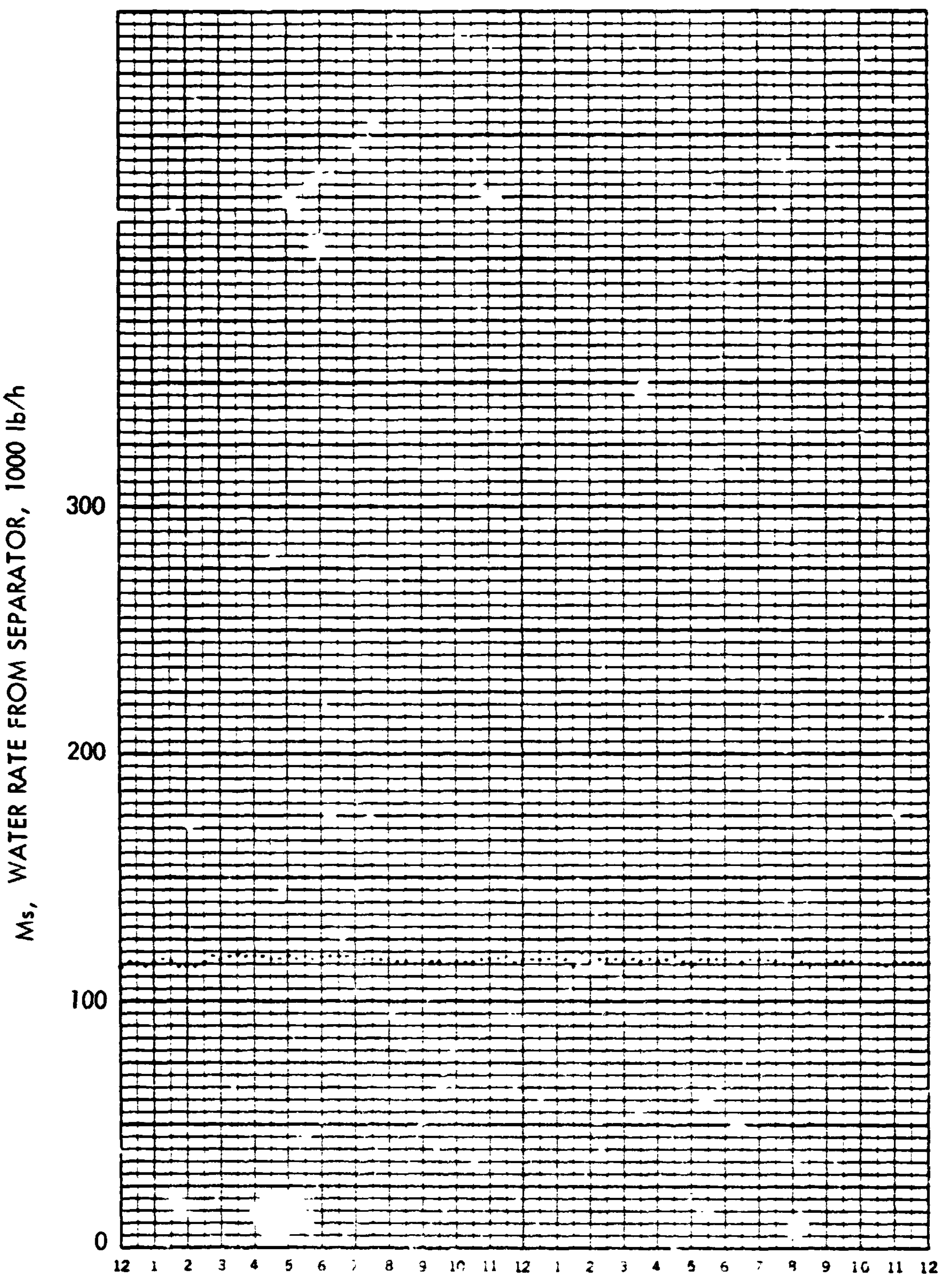

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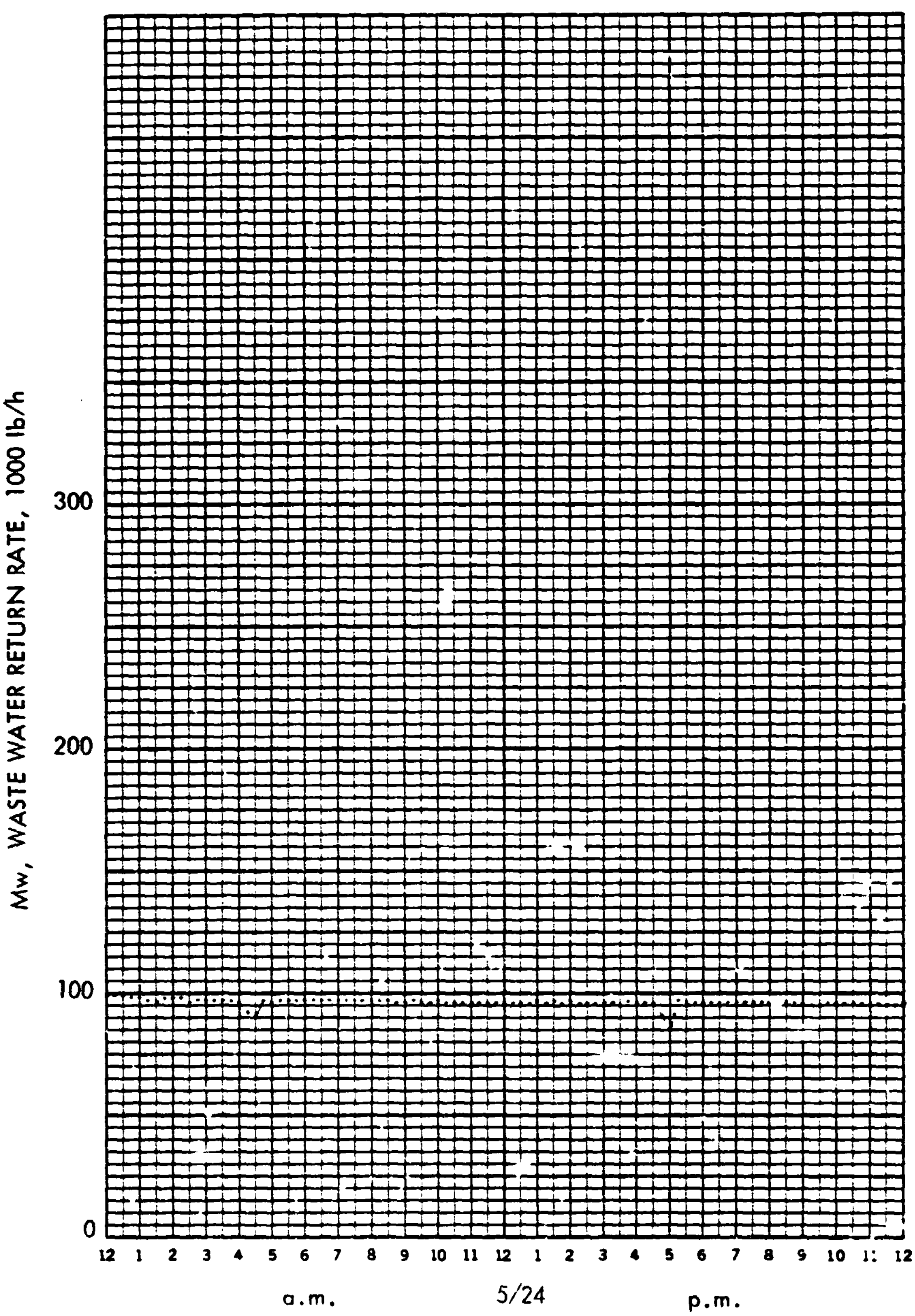

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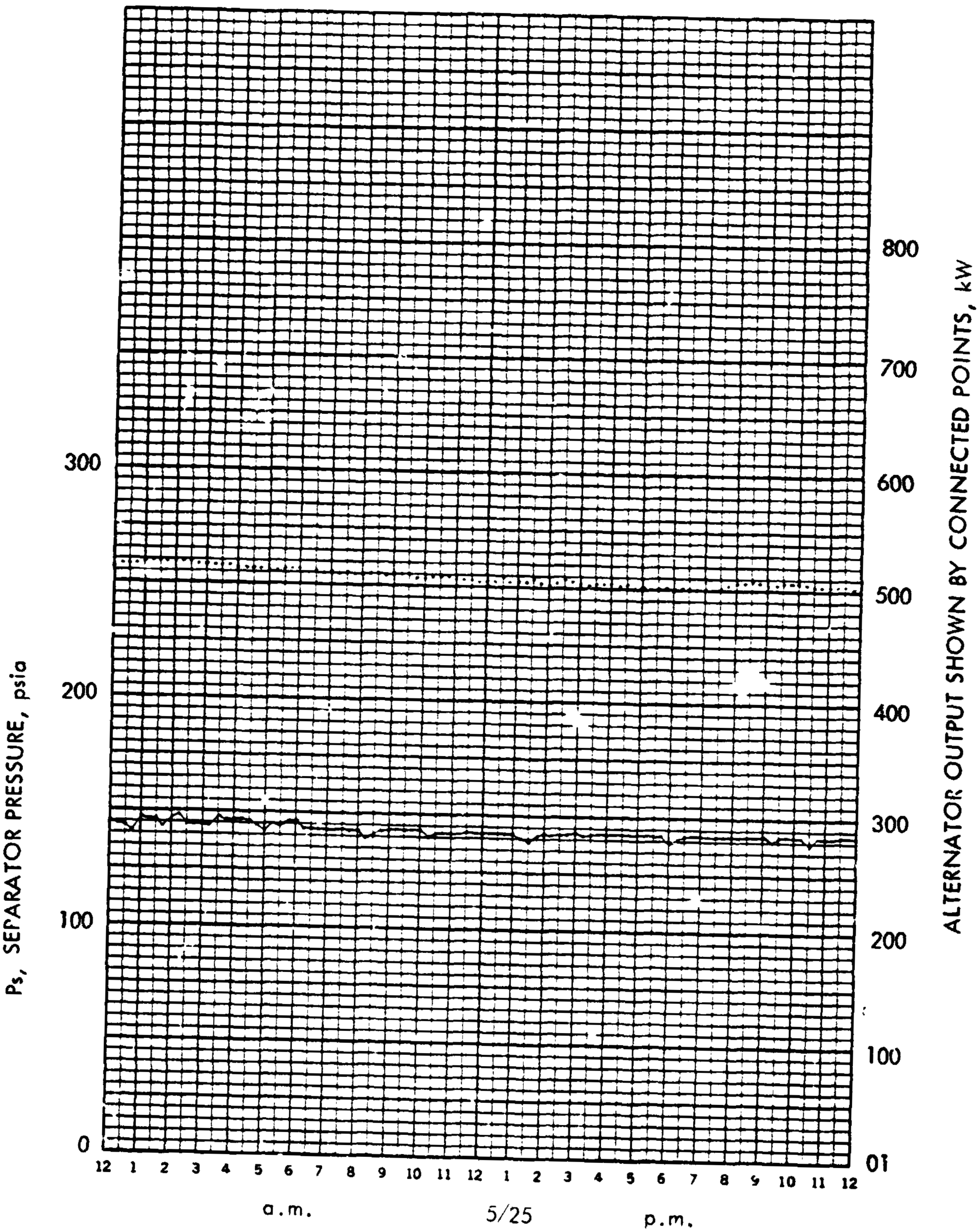

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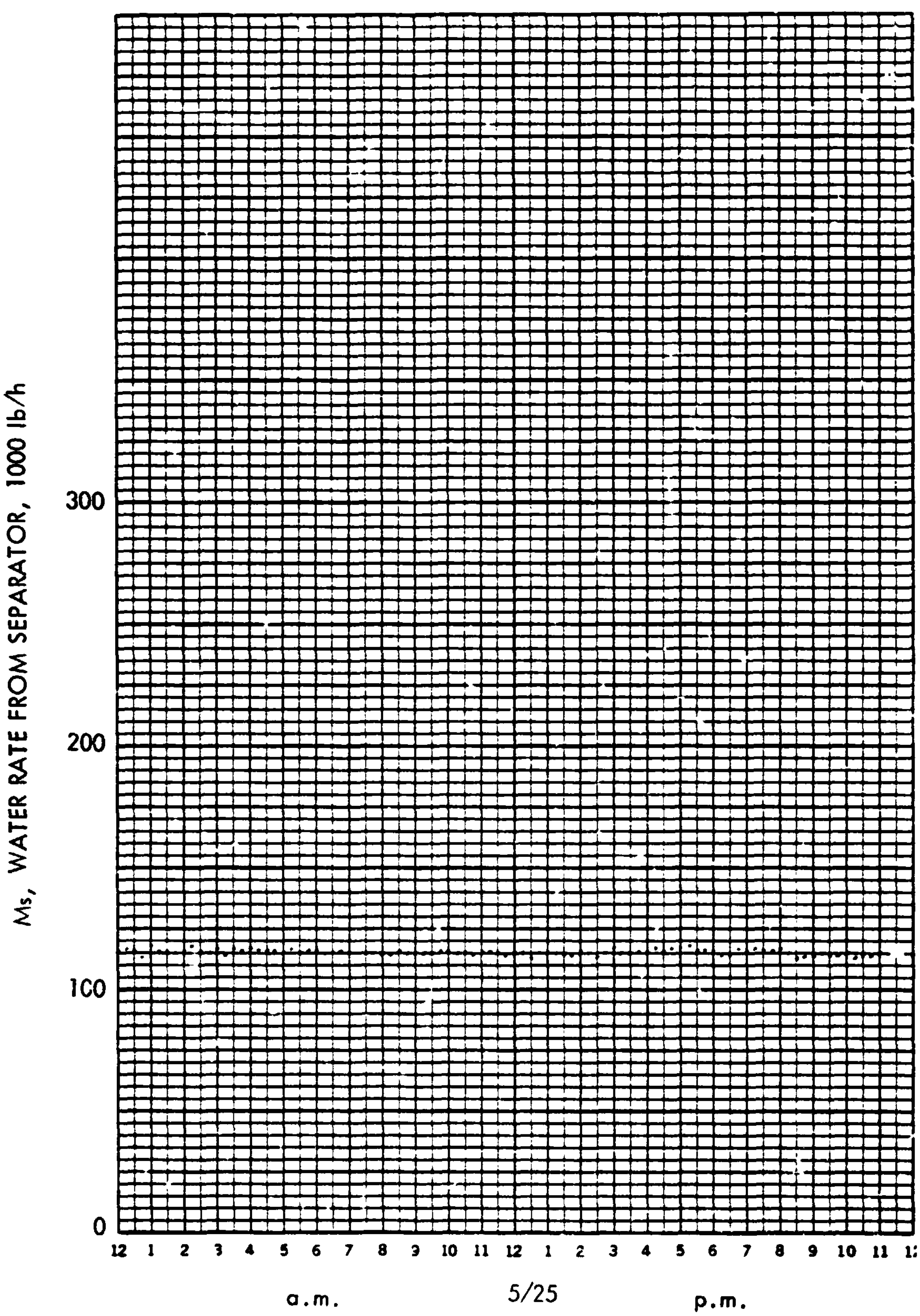

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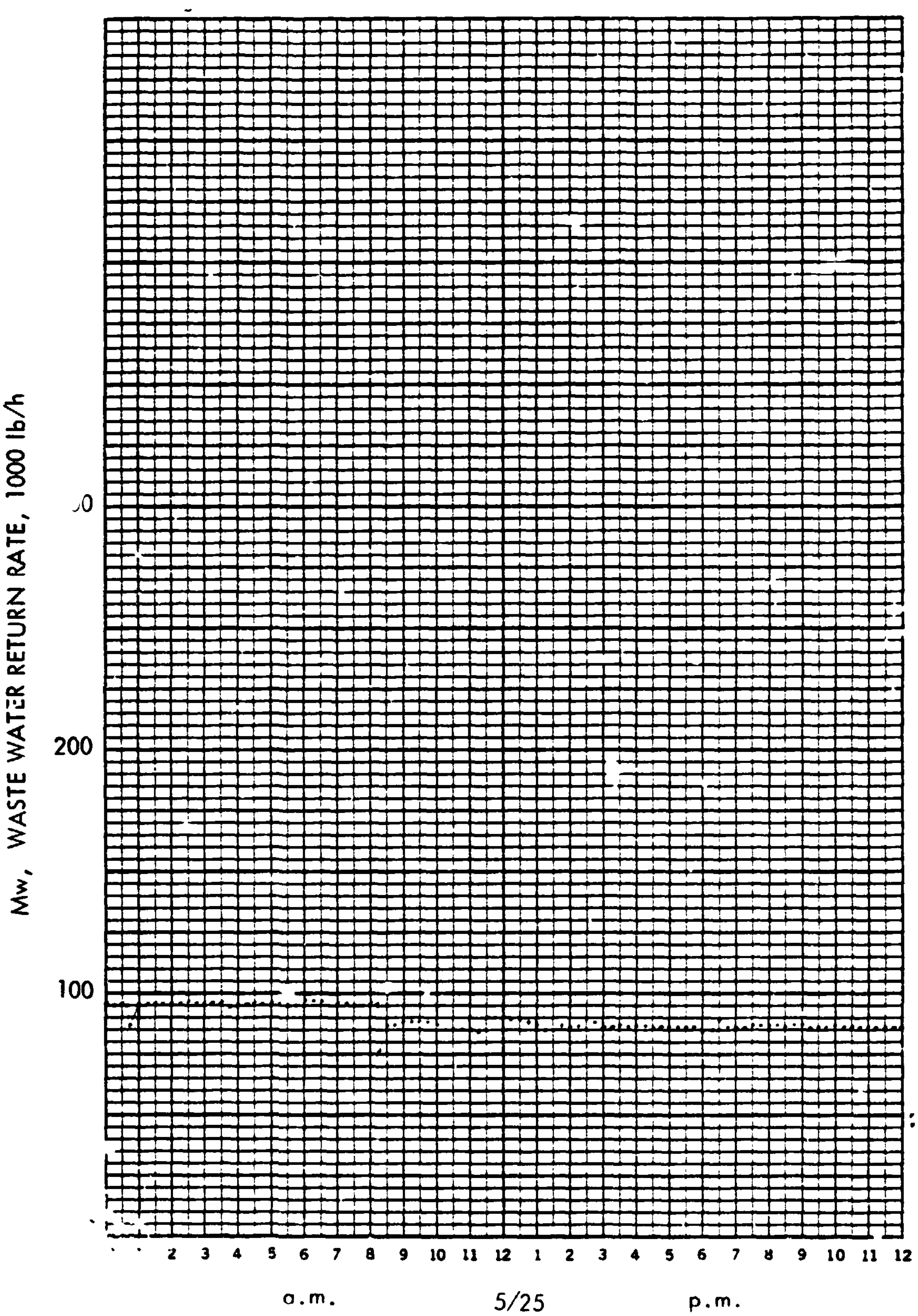
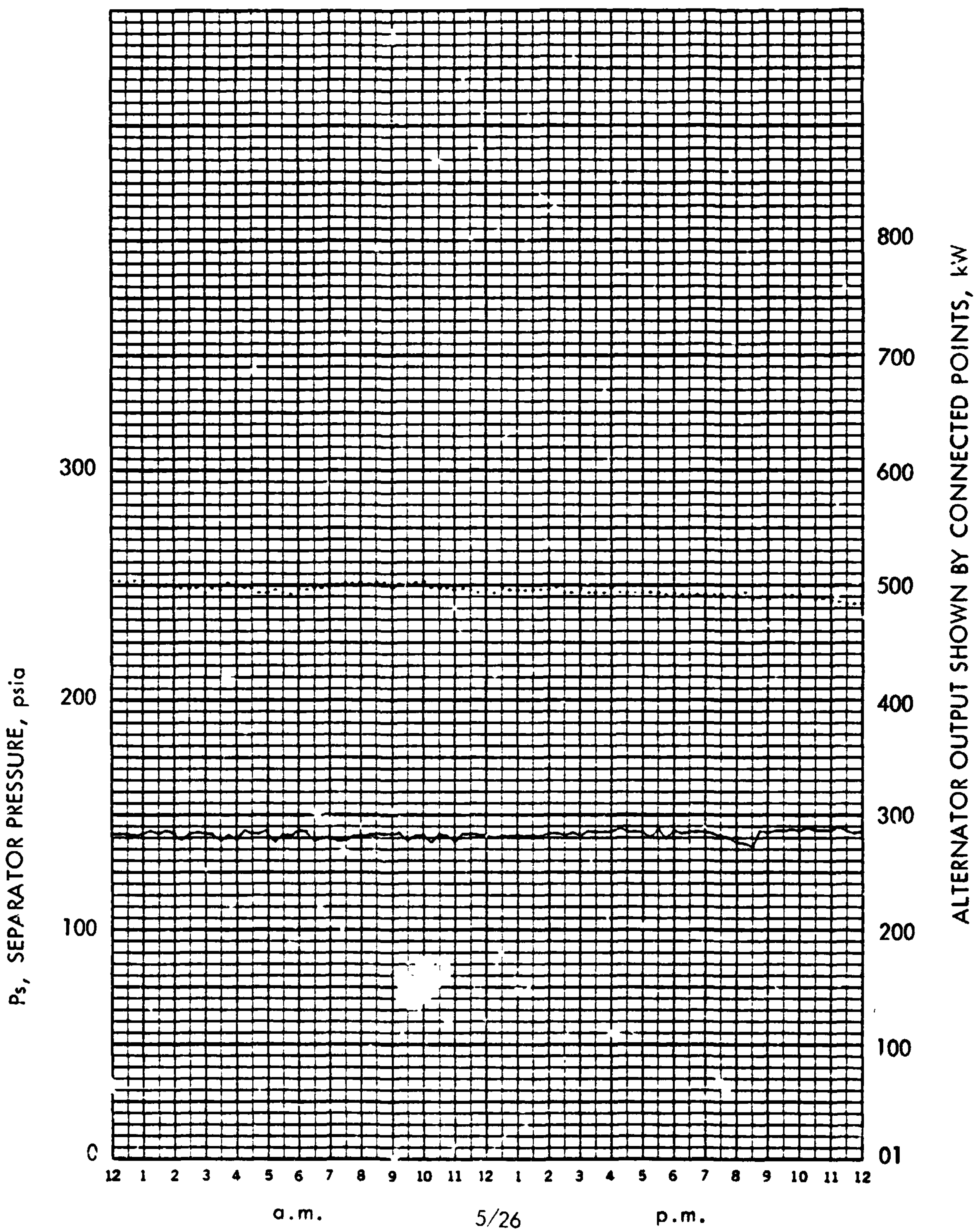
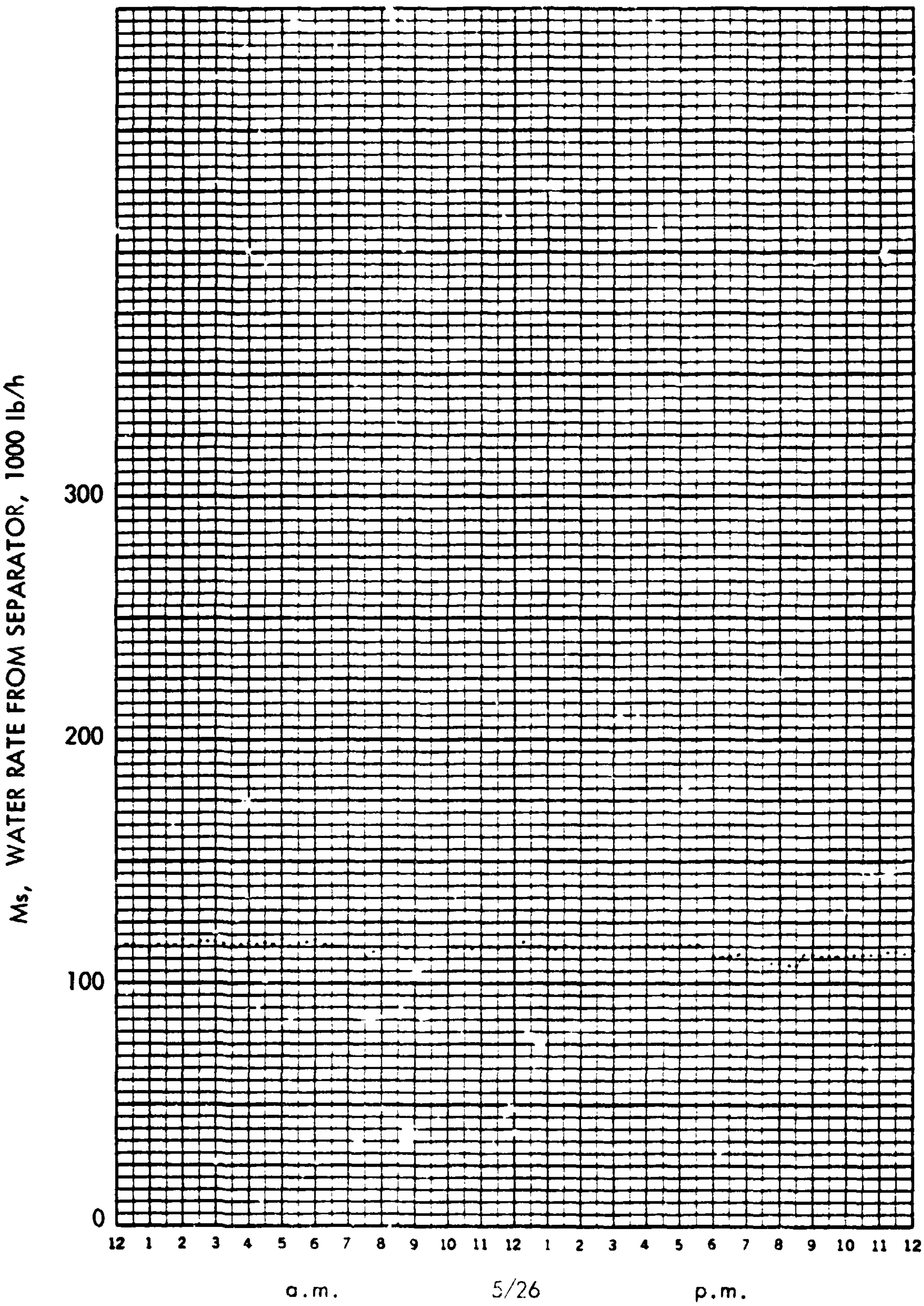
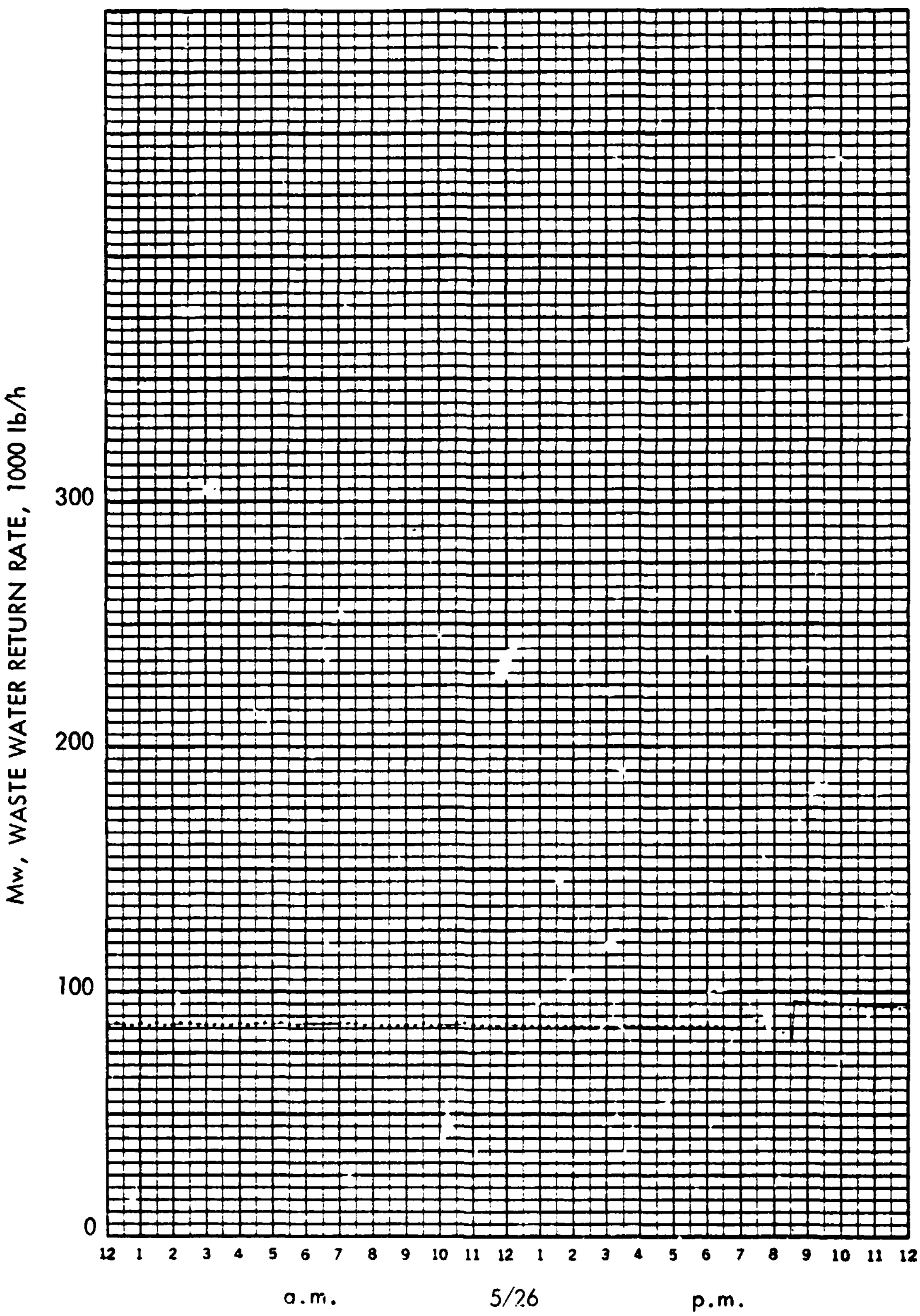



300
200
100
0
P_s, SEPARATOR PRESSURE, psia
800
700
600
500
400
300
200
100
0
ALTERNATOR OUTPUT SHOWN BY CONNECTED POINTS, kW
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
5/26
p.m.


Ms, WATER RATE FROM SEPARATOR, 1000 lb/h
300
200
100
0
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
5/26
p.m.


Mw, WASTE WATER RETURN RATE, 1000 lb/h
300
200
100
0
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
5/26
p.m.

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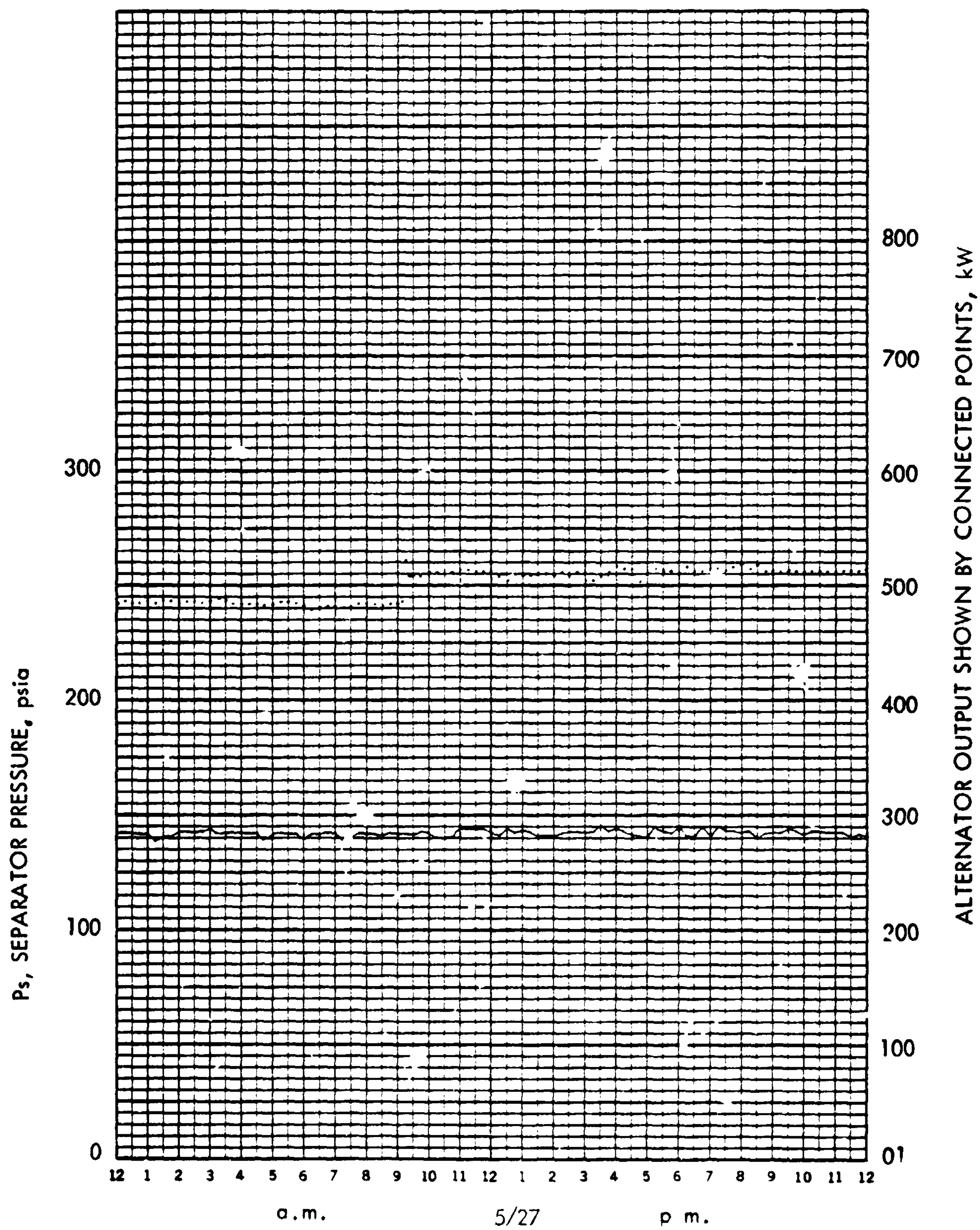

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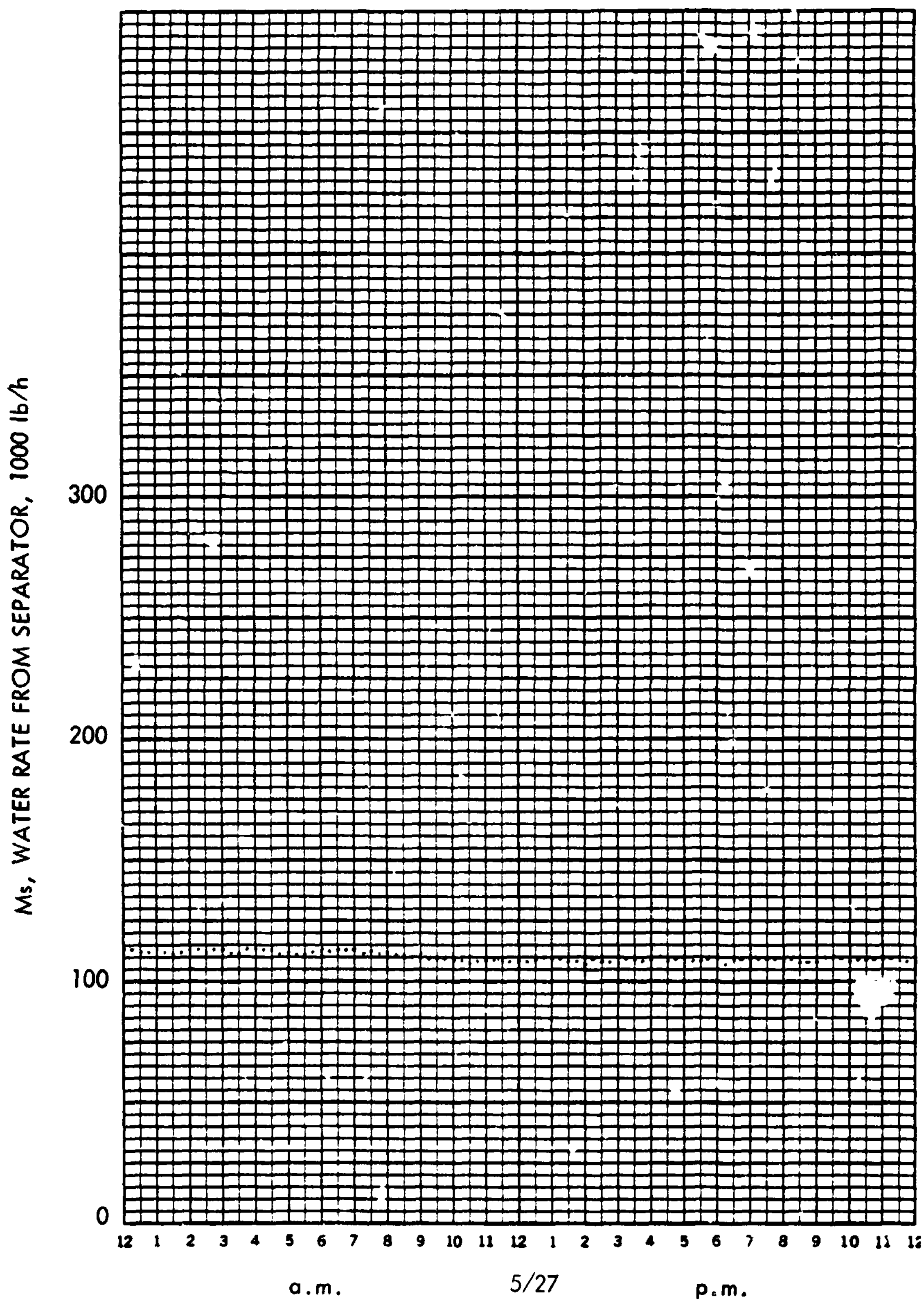

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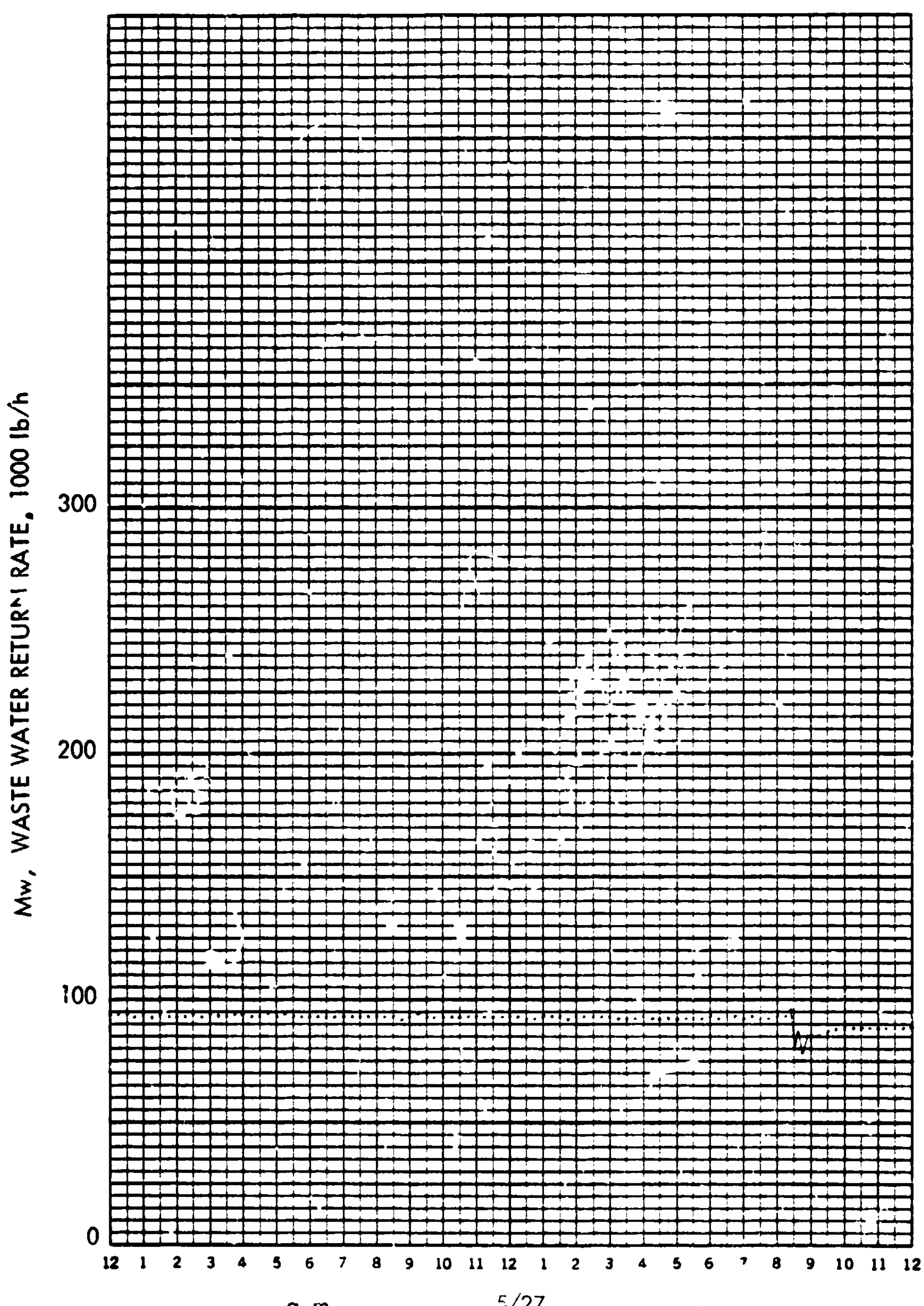

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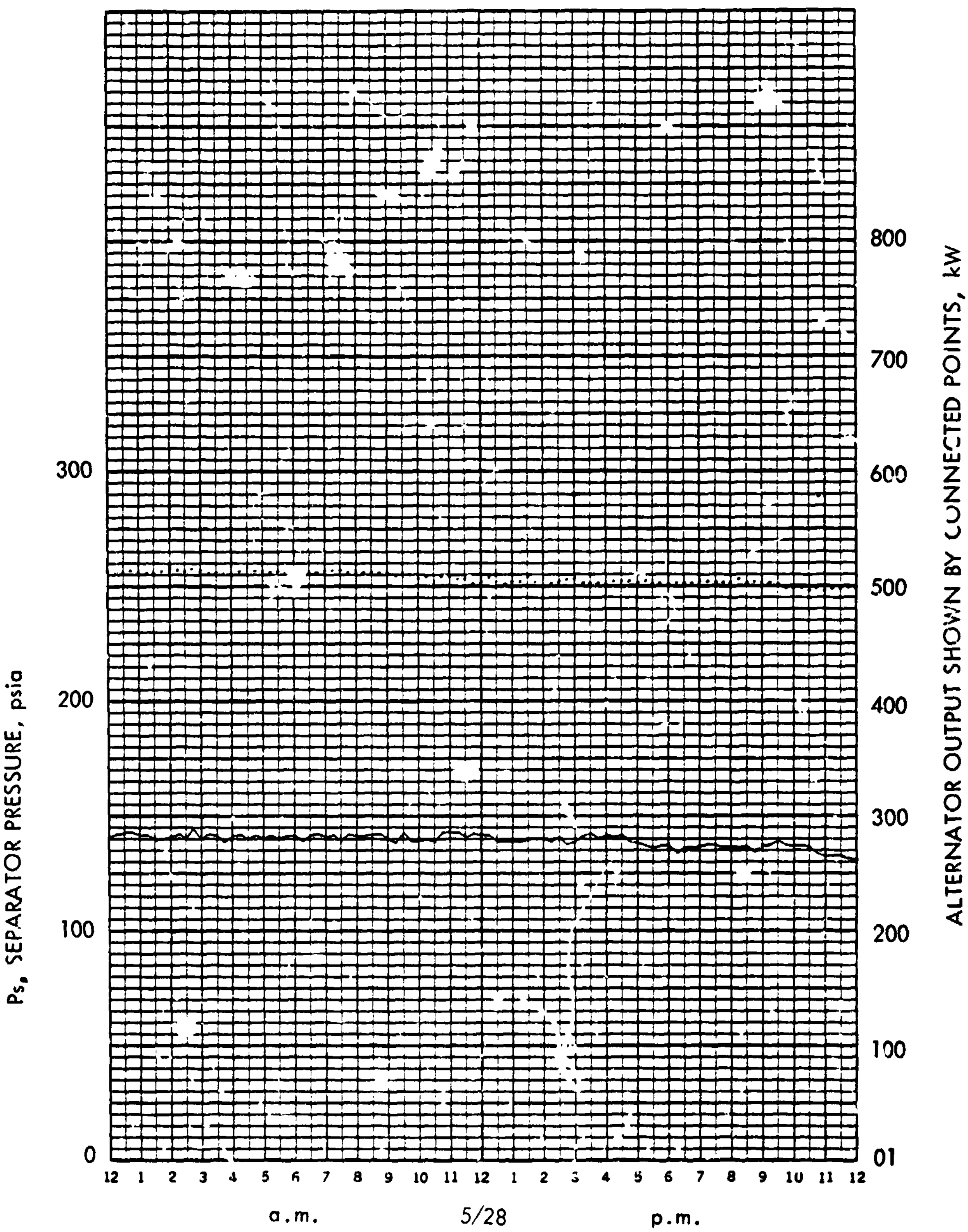

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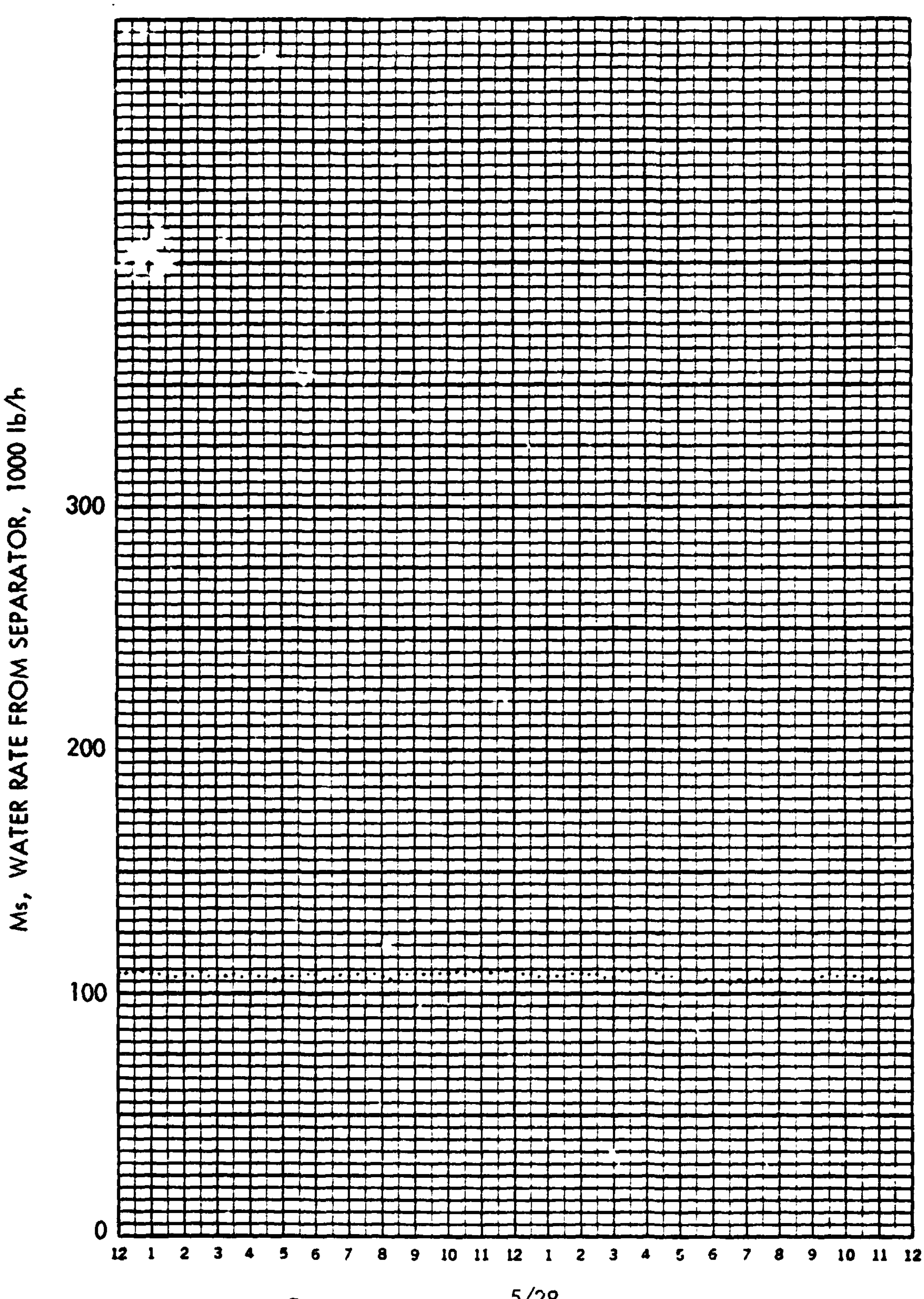

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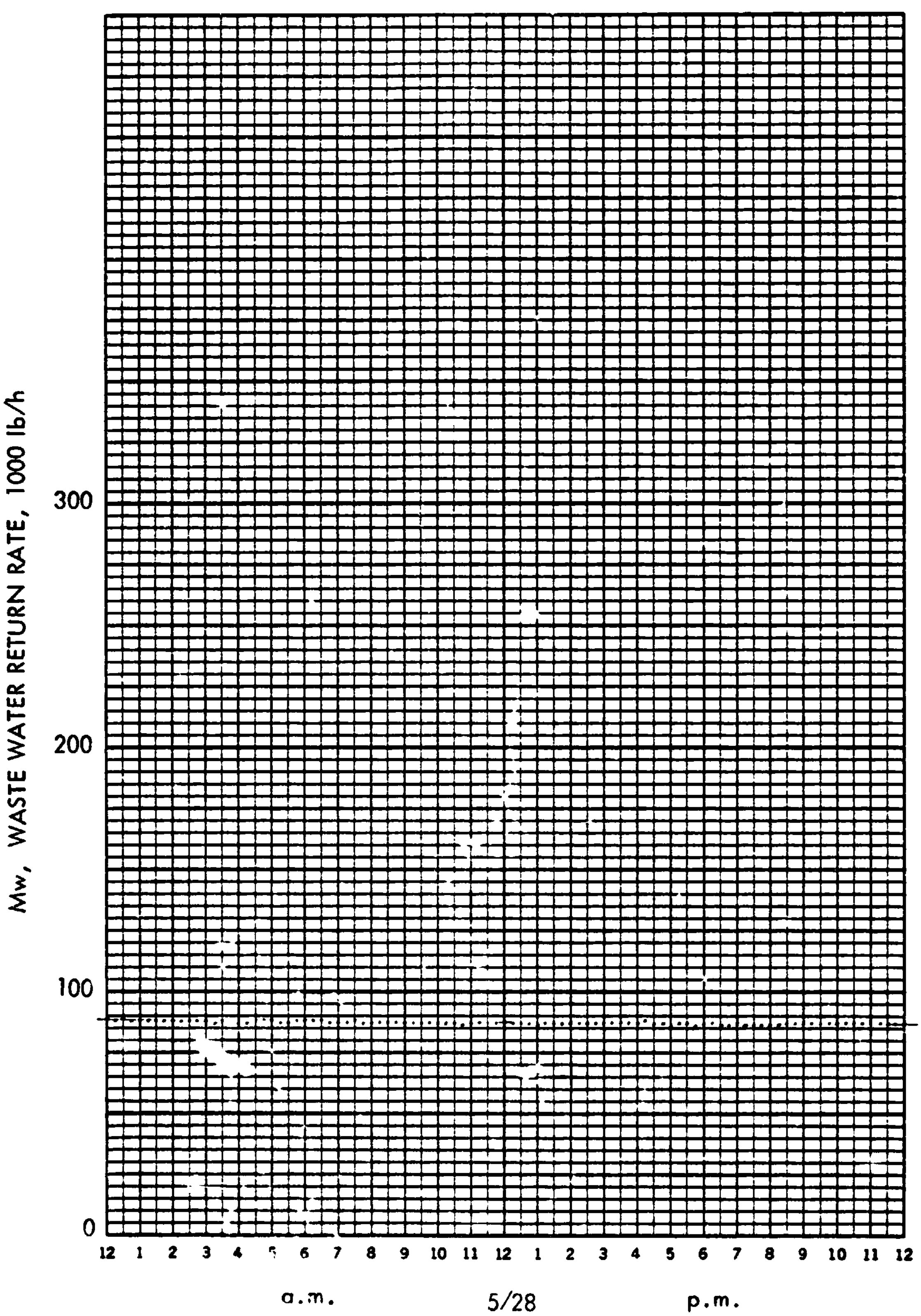

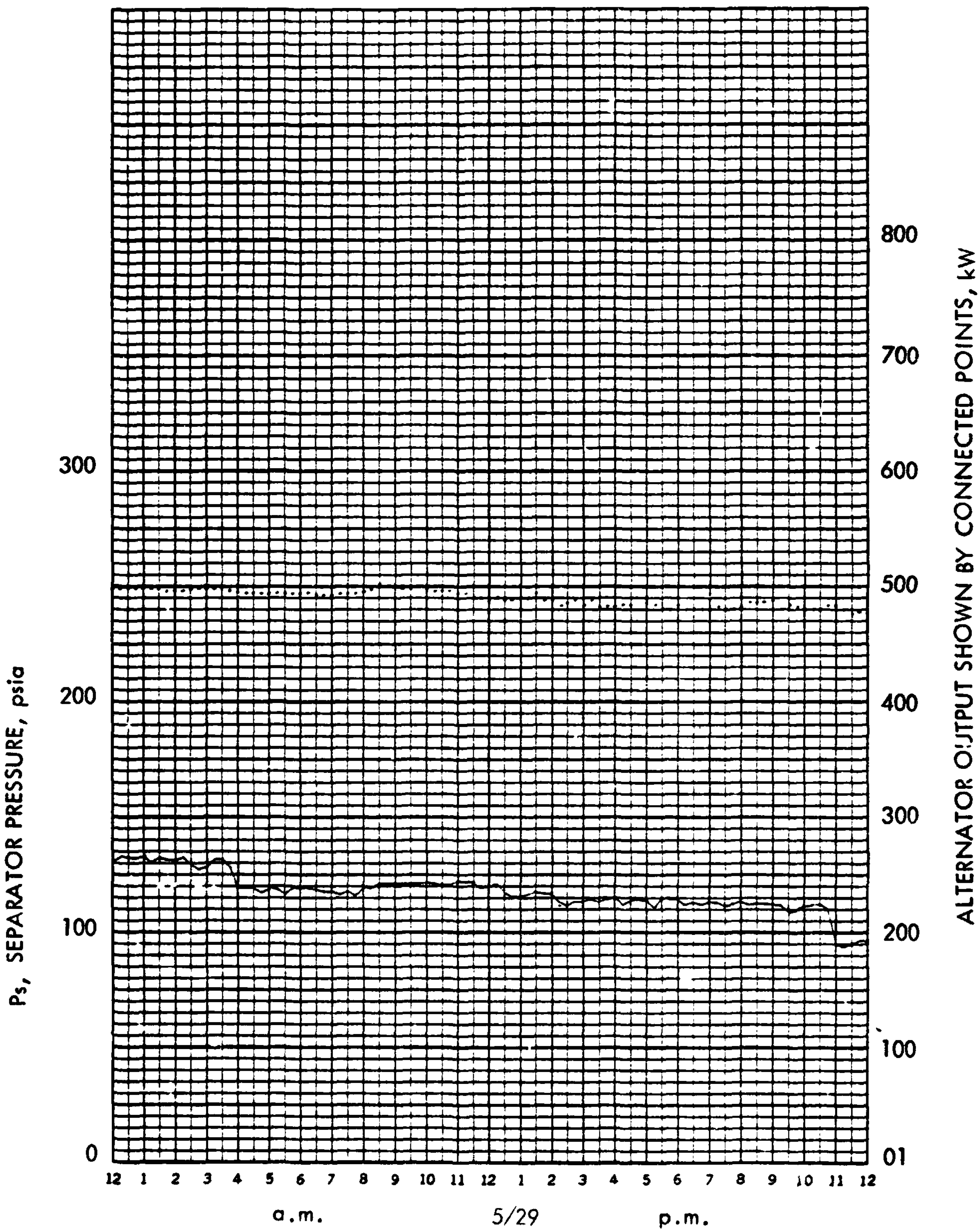
Ps, SEPARATOR PRESSURE, psia
300
200
100
0
ALTERNATOR OUTPUT SHOWN BY CONNECTED POINTS, kW
800
700
600
500
400
300
200
100
01
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
5/29
p.m.

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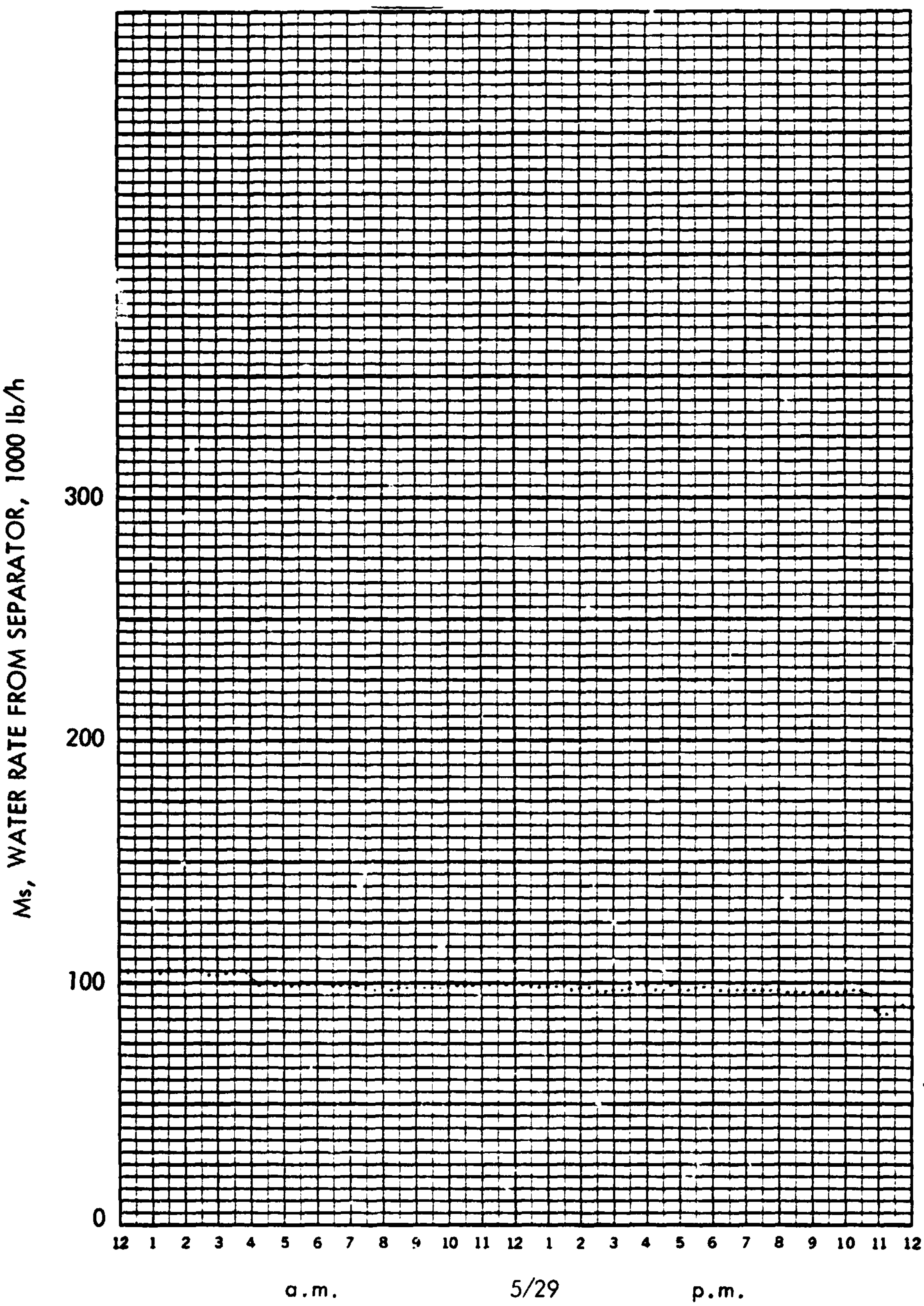

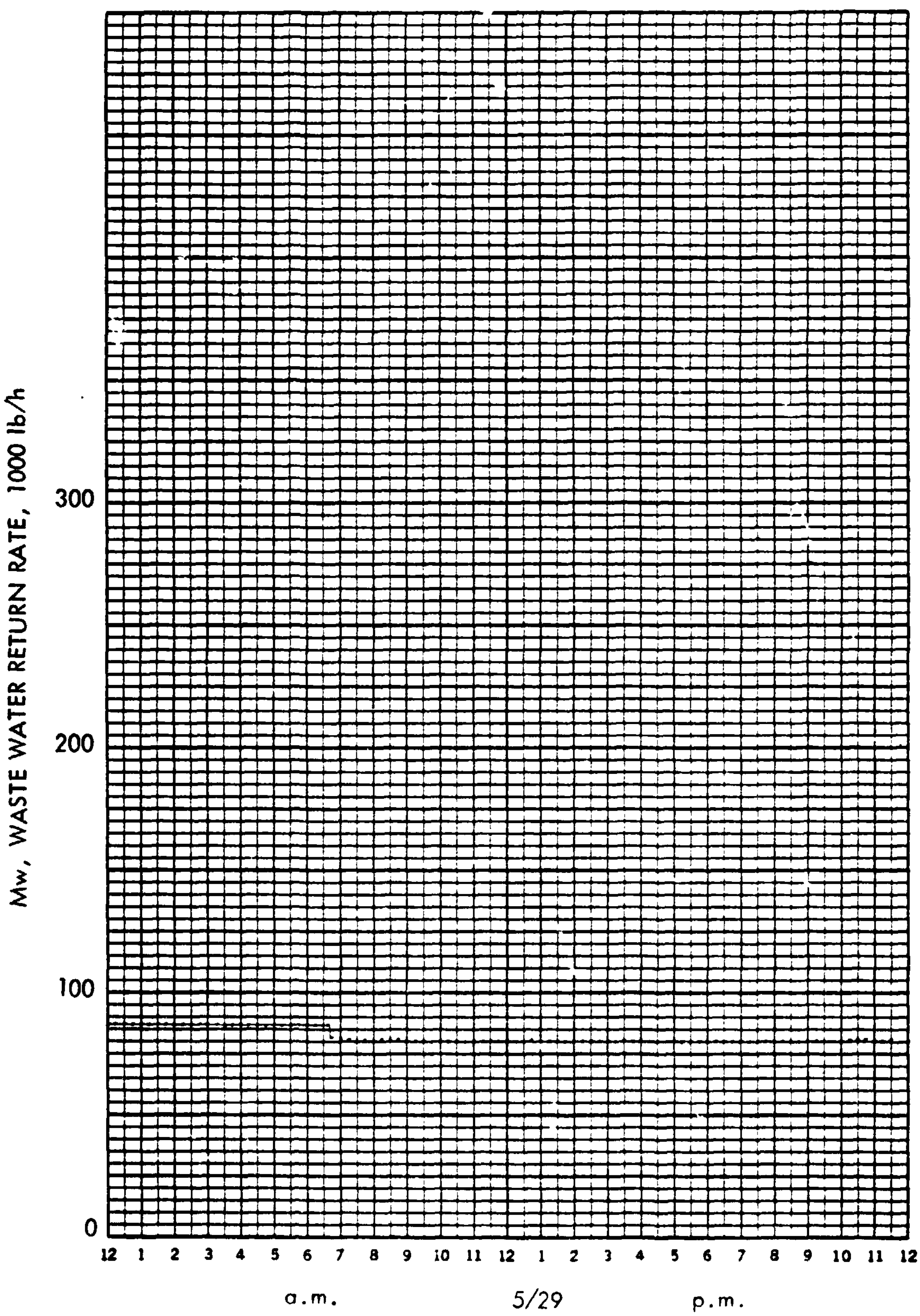
Mw, WASTE WATER RETURN RATE, 1000 lb/h
300
200
100
0
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
5/29
p.m.

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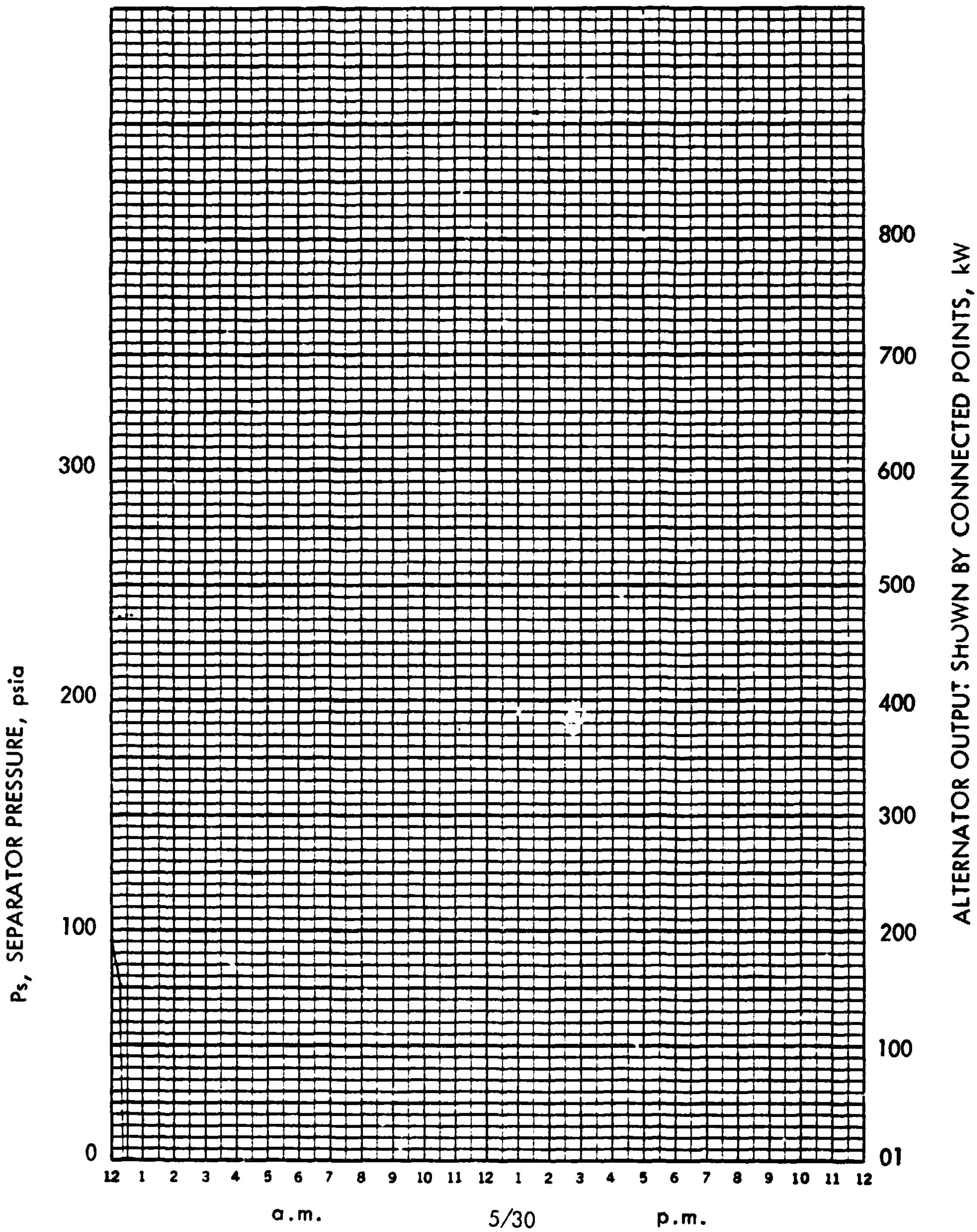

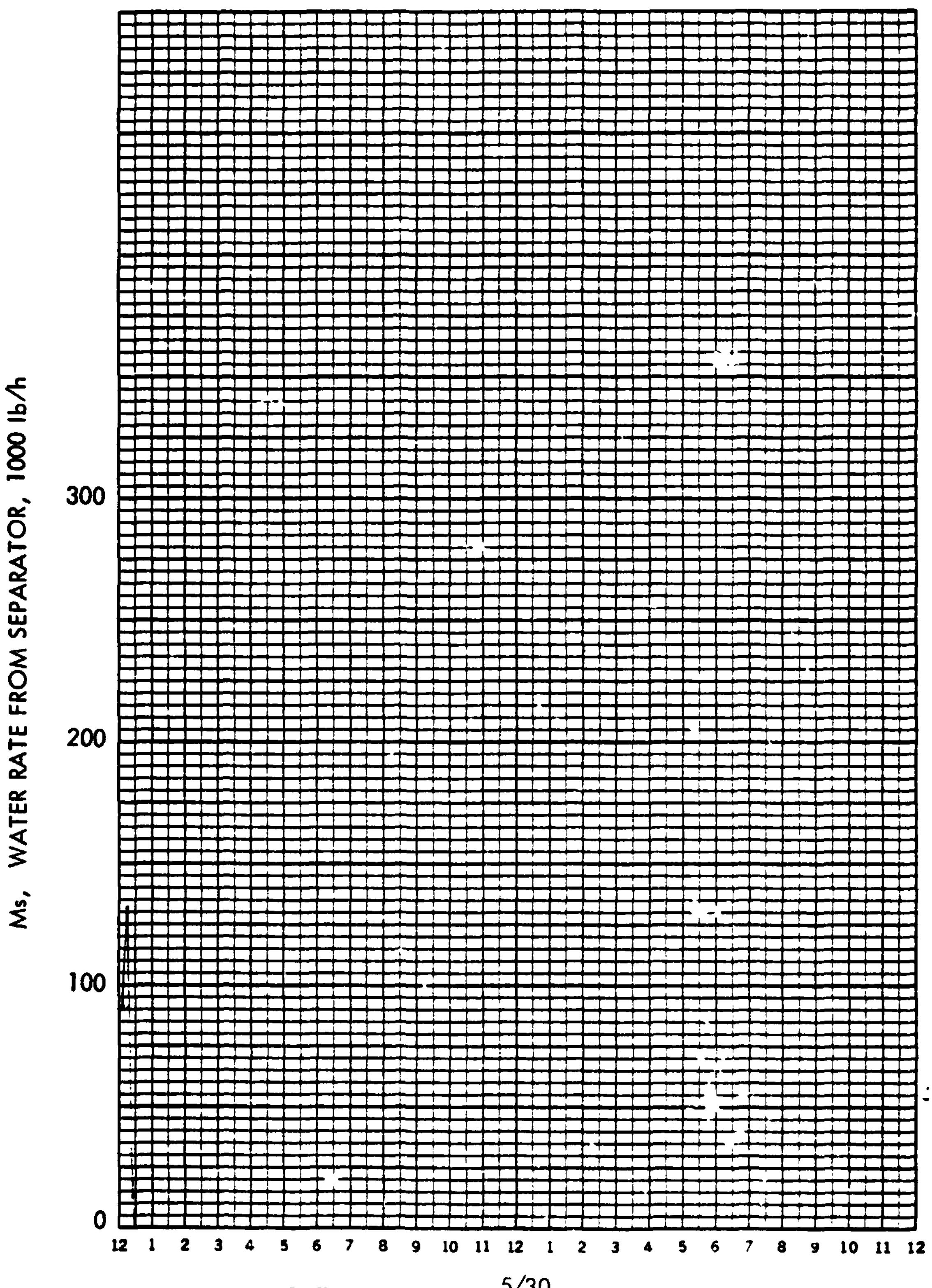
Ms, WATER RATE FROM SEPARATOR, 1000 lb/h
300
200
100
0
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
a.m.
5/30
p.m.

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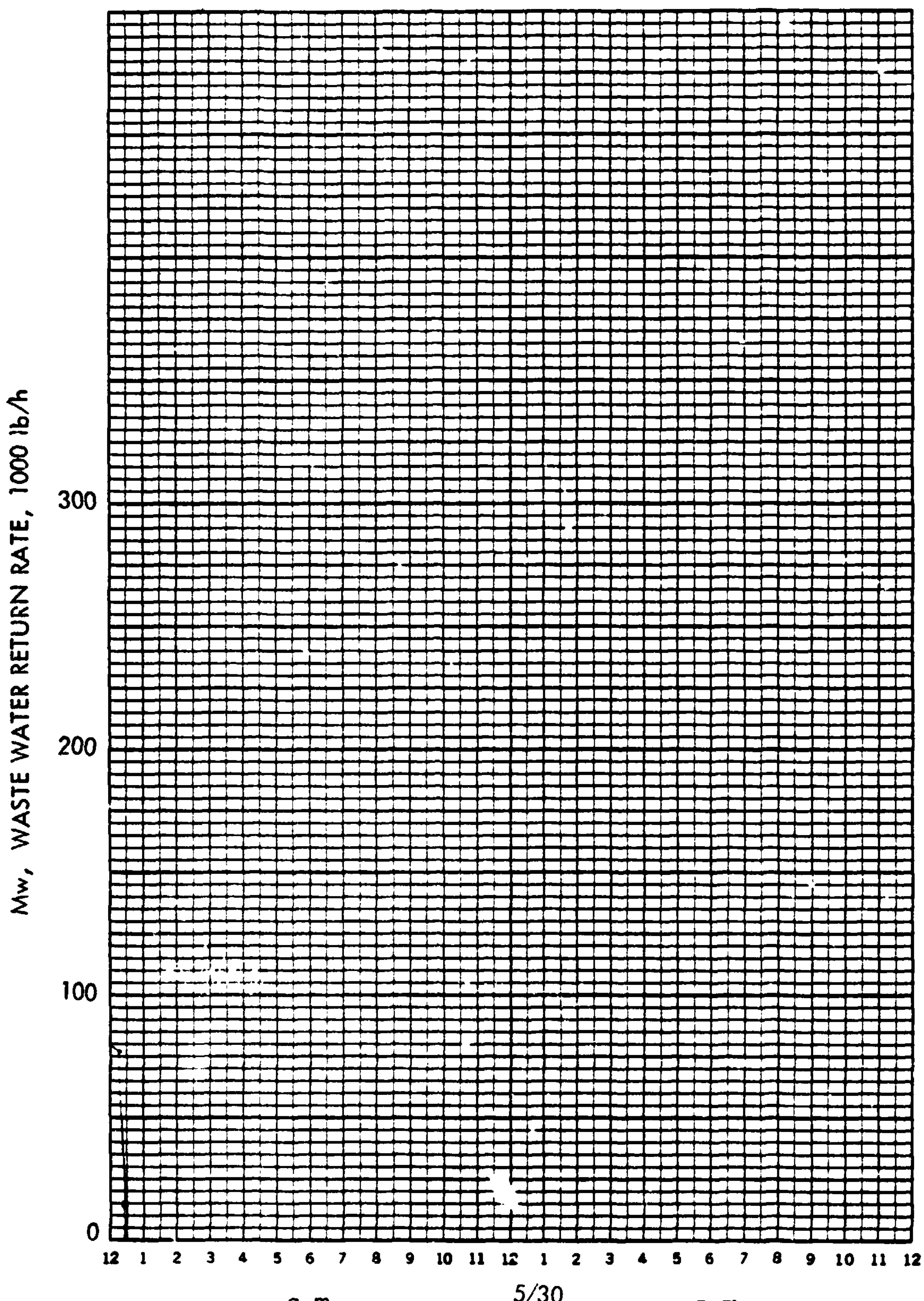

APPENDIX F

WATER ANALYSIS, WELL 54-3

APPENDIX F

TOTAL DISSOLVED SOLIDS

Well 54-3 Water Analysis

Constituent	Amount, ppm	Constituent	Amount
TDS	6440		
Na	2000	Ca	tr
Li	20	Mg	tr
K	400	Fe	tr
SiO_2	3600	As	tr
HCO_3	200	NO_3	tr
Cl	3600	NH_3	tr
SO_4	55	Pb	tr
B	28	H_2S	tr

6.9-7.0 pH conductivity 1.1 mho/meter

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APPENDIX G

ALTERNATOR AND GEAR BOX LOSSES

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APPENDIX G

POWER PLANT DRIVE TRAIN CALIBRATION RESULTS (3)

<u>Alternator loss @ 1800 rpm</u>

$$a = \left[35.585 + 5.28 \times 10^{-6} I^2 + \frac{4I}{1000}\right] \text{kW} \qquad (1978)$$

Where I = armature current

Original fan required 23.2 hp. Replacement quiet fan installed January 11, 1978 required 14.6 hp. Difference = 8.6 hp = 6.416 kW.

Hence,

$$a = \left[29.169 + 5.28 \times 10^{-6} I^2 + \frac{4I}{1000}\right] \text{kW} \qquad (\text{after Jan. 11, 1979})$$

<u>Gear Box Losses</u>

$$b = \left[8.5590 + 6.9750 \left(\frac{a + P_e}{1000}\right)\right] \text{kW} \qquad 3000 \text{ rpm input})$$

and

$$b = \left[11.0005 + 6.1069 \left(\frac{a + P_e}{1000}\right)\right] \text{kW} \qquad (4000 \text{ rpm input})$$

Where P_e = alternator output in kW

APPENDIX H

PROCESS CALCULATIONS

(Based on Process
No. 1, Figure 5-1)

MIXED PHASE EXPANDER OPERATION

Assume 1000 kW expander output, Steam Tables properties, conditions A thru E and
inlet quality x_1
Calculate flowrates

			0.0000	0	0.0000	0	0.0000	0	0.0000	0
1	h_{1f}		250.6300	1	298.4000	1	330.5100	1	355.3600	1
2	h_{1fg}		924.0000	2	888.8000	2	863.6000	2	843.0000	2
3	s_{1f}		0.4110	3	0.4740	3	0.5130	3	0.5435	3
4	s_{1fg}		1.2474	4	1.1286	4	1.0555	4	1.0018	4
5	h_{2f}		180.0700	5	180.0700	5	180.0700	5	180.0700	5
6	h_{2fg}		970.3000	6	970.3000	6	970.3000	6	970.3000	6
7	s_{2f}		0.3120	7	0.3120	7	0.3120	7	0.3120	7
8	s_{2fg}		1.4446	8	1.4446	8	1.4446	8	1.4446	8
9	v_3		0.0161	9	0.0161	9	0.0161	9	0.0161	9
A	p_1	psia	50.0000	A	100.0000	A	150.0000	A	200.0000	A
B	η_e		0.5000	B	0.5000	B	0.5000	B	0.5000	B
C	p_2	psia	14.6960	C	14.6960	C	14.6960	C	14.6960	C
D	h_3	[t_3=100°F]	67.9700	D	67.9700	D	67.9700	D	67.9700	D
E	h_4	[t_4=207°F]	175.0250	E	175.0250	E	175.0250	E	175.0350	E
I	v_4		0.0167	I	0.0167	I	0.0167	I	0.0167	I

x_1	0.00	***	0.00	***	0.00	***	0.00	***
$\dot{m}_1$ lb/h	1614235.86	***	597596.75	***	321354.17	***	267325.25	***
$\dot{m}_3/\dot{m}_e$	3.66	***	1.10	***	1.37	***	1.57	***
$\dot{m}_3$ lb/h	1299595.01	***	655667.99	***	522649.17	***	452052.53	***
$\dot{m}_3$ gpm	2211.15	***	1320.52	***	1050.99	***	903.62	***
$\dot{m}_4$ gpm	5641.34	***	2600.15	***	1980.25	***	1537.45	***
	0.05	***	0.05	***	0.05	***	0.05	***
	726254.24	***	354274.51	***	251414.95	***	206977.25	***
	1.69	***	1.48	***	1.73	***	1.32	***
	790576.76	***	523363.31	***	434512.56	***	385741.50	***
	1599.95	***	1252.46	***	877.95	***	775.68	***
	3154.45	***	1825.04	***	1436.55	***	1220.05	***
	0.10	***	0.10	***	0.10	***	0.10	***
	468572.63	***	251765.97	***	177337.72	***	154535.55	***
	1.50	***	1.96	***	2.03	***	2.27	***
	703557.44	***	467221.49	***	391418.17	***	350073.72	***
	1409.61	***	939.52	***	787.86	***	703.96	***
	2432.04	***	1495.05	***	1327.50	***	1043.31	***
	0.15	***	0.15	***	0.15	***	0.15	***
	345349.93	***	195266.15	***	143365.30	***	125528.47	***
	1.90	***	2.23	***	2.45	***	2.61	***
	659287.65	***	436266.67	***	355743.46	***	327882.83	***
	1323.73	***	877.29	***	735.46	***	659.17	***
	2095.34	***	1313.33	***	1271.14	***	942.67	***
	0.20	***	0.20	***	0.20	***	0.20	***
	274259.03	***	155477.22	***	124165.66	***	105685.36	***
	2.31	***	2.61	***	2.81	***	2.96	***
	633369.95	***	416655.83	***	346777.25	***	312565.36	***
	1273.50	***	837.65	***	701.37	***	628.53	***
	1886.84	***	1199.04	***	983.37	***	869.74	***
	0.25	***	0.25	***	0.25	***	0.25	***
	226353.10	***	134775.23	***	105241.57	***	91266.25	***
	2.72	***	2.99	***	3.17	***	3.30	***
	619316.75	***	403125.24	***	336646.95	***	301489.26	***
	1240.54	***	810.57	***	675.94	***	606.26	***
	1754.80	***	1119.53	***	920.35	***	816.71	***

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0.0000	0	0.0000	0	0.0000	0	0.0000	0	0.0000	0
373.6000	1	397.5400	1	409.6200	1	424.0000	1	437.2800	1
835.1000	2	835.0000	2	734.2000	2	750.5000	2	767.4000	2
0.5675	3	0.5873	3	0.6056	3	0.6214	3	0.6355	3
0.3538	4	0.9225	4	0.8510	4	0.8630	4	0.8375	4
180.0700	5	180.0700	5	180.0700	5	180.0700	5	180.0700	5
578.3000	6	578.3000	6	578.3000	6	578.3000	6	578.3000	6
0.3120	7	0.3120	7	0.3120	7	0.3120	7	0.3122	7
1.4445	8	1.4446	8	1.4446	8	1.4446	8	1.4446	8
0.0161	9	0.0161	9	0.0151	9	0.0151	9	0.0161	9
250.0000	A	300.0000	A	350.0000	A	400.0000	A	450.0000	A
0.5000	B	0.6000	B	0.6000	B	0.5000	B	0.6000	B
14.6962	C	14.6960	C	14.6960	C	14.6962	C	14.6960	C
67.5700	D	67.5700	D	67.5700	D	67.5700	D	67.5700	D
175.0356	E	175.0356	E	175.0350	E	175.0350	E	175.0350	E
0.0167	I	0.0167	I	0.0167	I	0.0167	I	0.0167	I
0.00	***	0.00	***	0.00	***	0.00	***	0.00	***
233920.86	***	199204.93	***	175470.11	***	157503.95	***	143007.93	***
1.74	***	1.88	***	2.01	***	2.12	***	2.23	***
467200.39	***	376660.69	***	352714.23	***	334396.02	***	318298.59	***
816.63	***	757.42	***	709.26	***	672.42	***	640.06	***
1333.17	***	1196.33	***	1098.34	***	1022.86	***	959.26	***
0.05	***	0.05	***	0.05	***	0.05	***	0.05	***
179450.75	***	149552.03	***	134783.46	***	123240.42	***	113744.86	***
2.08	***	2.21	***	2.33	***	2.43	***	2.53	***
357742.84	***	331323.80	***	313516.55	***	299621.86	***	287405.53	***
711.33	***	666.25	***	630.45	***	602.50	***	577.94	***
1090.03	***	1000.27	***	932.22	***	879.32	***	834.17	***
0.10	***	0.10	***	0.10	***	0.10	***	0.10	***
134672.63	***	120024.04	***	108411.16	***	101216.29	***	94422.33	***
2.41	***	2.53	***	2.64	***	2.74	***	2.83	***
327105.21	***	304103.16	***	289079.54	***	277375.22	***	267007.89	***
643.72	***	611.51	***	581.30	***	557.57	***	536.92	***
950.67	***	881.55	***	826.64	***	787.66	***	751.57	***
0.15	***	0.15	***	0.15	***	0.15	***	0.15	***
110491.24	***	100036.94	***	92077.96	***	85273.37	***	80711.79	***
2.74	***	2.86	***	2.96	***	3.05	***	3.13	***
303244.02	***	285948.40	***	272364.06	***	261711.61	***	252533.98	***
609.79	***	575.01	***	547.73	***	526.27	***	507.61	***
860.34	***	802.63	***	757.66	***	722.76	***	692.96	***
0.20	***	0.20	***	0.20	***	0.20	***	0.20	***
93364.31	***	85756.30	***	79435.64	***	74566.61	***	70476.67	***
3.08	***	3.18	***	3.27	***	3.36	***	3.43	***
289324.51	***	272976.95	***	260354.99	***	250241.75	***	241730.32	***
581.79	***	546.92	***	523.34	***	503.20	***	486.09	***
797.03	***	745.96	***	706.47	***	675.42	***	645.22	***
0.25	***	0.25	***	0.25	***	0.25	***	0.25	***
81778.18	***	75043.56	***	69523.14	***	65894.01	***	62547.46	***
3.41	***	3.51	***	3.59	***	3.66	***	3.73	***
279027.27	***	263246.31	***	251644.26	***	241440.93	***	233358.11	***
561.09	***	529.35	***	504.82	***	465.51	***	469.25	***
750.19	***	703.45	***	667.43	***	639.06	***	615.32	***

0.0000	0	0.0000	0	0.0000	0	0.0000	0
445.4000	1	460.5000	1	471.6000	1	421.5000	1
755.0000	2	741.1000	2	731.6000	2	720.5000	2
[illegible]	3	0.6600	3	0.6720	3	0.6525	3
[illegible]	4	0.7535	4	0.7734	4	0.7548	4
[illegible].7900	5	120.0700	5	120.0720	5	130.0700	5
970.3000	6	970.3000	6	970 3000	6	970.3000	6
0.3120	7	0.3120	7	[illegible]120	7	0.[illegible]	7
1.4446	8	1.4445	8	[illegible]46	8	[illegible]	8
0.0161	9	0.0161	9	0.0161	9	0.0[illegible]	9
500.0000	A	550.0000	A	600.0000	A	550.0000	A
0.6000	B	0.6000	B	0.6000	B	0.6000	B
14.6560	C	14.5960	C	14.6960	C	14.6550	C
57.9700	D	67.9700	D	67.9700	D	67.9700	D
175.0350	E	175.0350	E	175.0350	E	175.0350	E
0.0167	I	0.0157	I	0.0167	I	0.0167	I

0.06	***	0.30	***	0.08	***	0.00	***
131743.23	***	122372.50	***	114390.27	***	107581.08	***
2.32	***	2.41	***	2.49	***	2.57	***
305727.65	***	294744.10	***	264377.81	***	276365.25	***
614.78	***	592.69	***	573.05	***	555.74	***
969.63	***	967.37	***	338.46	***	798.39	***

0.05	***	0.05	***	0.05	***	0.05	***
105191.41	***	93829.72	***	94261.04	***	85508.33	***
2.61	***	2.70	***	2.77	***	2.85	***
277698.53	***	269159.44	***	261438.42	***	254700.99	***
556.40	***	541.25	***	525.82	***	512.17	***
798.26	***	767.25	***	735.80	***	715.76	***

0.10	***	0.10	***	0.10	***	0.10	***
89341.13	***	84271.86	***	80124.94	***	76634.38	***
2.91	***	2.98	***	3.06	***	3.12	***
256762.34	***	251540.56	***	245022.90	***	239265.25	***
520.34	***	505.93	***	492.71	***	481.14	***
723.03	***	698.30	***	676.25	***	656.90	***

0.15	***	0.15	***	0.15	***	0.15	***
76512.11	***	72520.04	***	69755.66	***	66956.07	***
3.20	***	3.27	***	3.34	***	3.40	***
245124.39	***	238662.37	***	233840.55	***	227716.62	***
492.91	***	479.93	***	466.21	***	457.51	***
668.32	***	647.93	***	629.23	***	612.34	***

0.20	***	0.20	***	0.20	***	0.20	***
67130.94	***	64263.45	***	61727.11	***	59514.43	***
3.50	***	3.56	***	3.62	***	3.68	***
234630.75	***	228853.38	***	223462.49	***	216745.61	***
472.21	***	460.13	***	449.35	***	439.37	***
627.91	***	609.53	***	593.03	***	578.63	***

0.25	***	0.25	***	0.25	***	0.25	***
59796.98	***	57444.07	***	55355.90	***	53534.74	***
3.75	***	3.85	***	3.90	***	3.95	***
226785.62	***	221119.66	***	216620.34	***	211577.34	***
456.04	***	444.64	***	434.39	***	425.46	***
535.94	***	575.26	***	564.31	***	551.28	***

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MIXED PHASE EXPANDER OPERATION

Assume 1000 kW expander output, Steam Tables properties, conditions A thru E and inlet quality x_1
Calculate flowrates

			0.0000	0	0.0000	0	0.0000	0	0.0000	0
1	h_{1f}		250.0500	1	298.4000	1	330.5100	1	355.3600	1
2	h_{1fg}		924.0000	2	888.8000	2	863.6000	2	843.0000	2
3	s_{1f}		0.4110	3	0.4740	3	0.5139	3	0.5435	3
4	s_{1fg}		1.2474	4	1.1286	4	1.0556	4	1.0016	4
5	h_{2f}		109.3700	5	109.3700	5	109.3700	5	109.3700	5
6	h_{2fg}		1013.2000	6	1013.2000	6	1013.2000	6	1013.2000	6
7	s_{2f}		0.2008	7	0.2008	7	0.2008	7	0.2008	7
8	s_{2fg}		1.6855	8	1.6855	8	1.6855	8	1.6855	8
9	v_3		0.0161	9	0.0161	9	0.0161	9	0.0161	9
A	p_1	psia	50.0000	A	100.0000	A	150.0000	A	200.0000	A
B	η_e		0.5000	B	0.5000	B	0.5000	B	0.5000	B
C	p_2	psia	3.0000	C	3.0000	C	3.0000	C	3.0000	C
D	h_3	[t_3=100°F]	67.9700	D	67.9700	D	67.9700	D	67.9700	D
E	h_4	[t_4=136.48°F]	104.3752	E	104.3752	E	104.3752	E	104.3752	E
I	v_4		0.0163	I	0.0163	I	0.0163	I	0.0163	I
	x_1		0.00	***	0.00	***	0.00	***	0.00	***
	$\dot{m}$	lb/h	396039.35	***	229343.49	***	172440.60	***	142265.35	***
	$\dot{m}_3/\dot{m}_e$		3.77	***	4.92	***	5.57	***	6.24	***
	$\dot{m}_3$	lb/h	1491423.79	***	1128568.45	***	977384.13	***	887062.51	***
	$\dot{m}_3$	gpm	2992.89	***	2269.45	***	1965.40	***	1783.77	***
	$\dot{m}_4$	gpm	3829.53	***	2755.15	***	2332.91	***	2095.43	***
			0.05	***	0.05	***	0.05	***	0.05	***
			245560.46	***	161043.42	***	128021.25	***	109742.19	***
			4.39	***	5.97	***	6.67	***	7.19	***
			1206225.66	***	961170.58	***	853154.69	***	786673.40	***
			2425.16	***	1932.75	***	1715.61	***	1581.96	***
			2947.13	***	2276.90	***	1990.71	***	1814.95	***
			0.10	***	0.10	***	0.10	***	0.10	***
			178993.90	***	124034.26	***	101773.34	**	88793.14	***
			6.02	***	7.02	***	7.66	***	8.15	***
			1077030.22	***	870566.16	***	779951.24	***	724017.16	***
			2165.77	***	1750.64	***	1568.13	***	1455.91	***
			2546.39	***	2016.13	***	1788.75	***	1649.13	***
			0.15	***	0.15	***	0.15	***	0.15	***
			140520.20	***	100937.57	***	84455.97	***	74745.89	***
			7.14	***	8.06	***	8.66	***	9.11	***
			1003523.24	***	813614.51	***	731472.88	***	681185.61	***
			2017.96	***	1635.45	***	1470.90	***	1369.76	***
			2321.14	***	1855.96	***	1655.48	***	1533.73	***
			0.20	***	0.20	***	0.20	***	0.20	***
			115671.06	***	85053.44	***	72169.56	***	64536.14	***
			8.27	***	9.11	***	9.66	***	10.07	***
			956032.56	***	774901.29	***	697157.29	***	650055.02	***
			1922.47	***	1558.23	***	1401.90	***	1307.18	***
			2174.34	***	1744.79	***	1560.95	***	1449.65	***
			0.25	***	0.25	***	0.25	***	0.25	***
			98241.53	***	77493.42	***	63026.85	***	56790.35	***
			9.39	***	10.16	***	10.65	***	11.07	***
			922636.27	***	746565.24	***	671550.66	***	625406.81	***
			1855.71	***	1501.25	***	1350.48	***	1257.62	***
			2071.69	***	1653.85	***	1490.41	***	1366.14	***

ORIGINAL PAGE IS
OF POOR QUALITY

0.0000	0	0.0000	0	0.0000	0	0.0000	0	0.0000	0
[illegible]	1	353.8400	1	405.5900	1	424.0000	1	477.3200	1
225.1000	2	909.0000	2	754.2000	2	760.5300	2	767.4000	2
0.5675	3	0.5375	3	0.5055	3	0.6214	3	0.6355	3
0.3599	4	2.9225	4	0.6910	4	0.3630	4	0.8378	4
[illegible]	5	109.3700	5	109.3700	5	109.3700	5	109.3700	5
[illegible]	6	1013.2000	6	1013.2000	6	1013.2000	6	1013.2000	6
[illegible]	7	0.2006	7	0.2000	7	0.2008	7	0.2000	7
1.6055	8	1.6855	8	1.6855	8	1.6955	8	1.6855	8
0.0161	9	0.0161	9	0.0161	9	0.0161	9	0.0161	9
[illegible]	A	300.0000	A	350.0000	A	400.0000	A	450.0000	A
0.6000	B	0.6000	B	0.6000	B	0.6000	B	0.6000	B
3.0000	C	3.0000	C	3.0000	C	3.0000	C	3.0000	C
67.9700	D	67.9700	D	67.9700	D	67.9700	D	67.9700	D
104.3752	E	104.3752	E	104.3752	E	104.3752	E	104.3752	E
0.0163	I	0.0163	I	0.0163	I	0.9163	I	0.0163	I
0.00	***	0.00	***	0.00	***	0.00	***	0.00	***
[illegible]	***	109965.30	***	99923.92	***	92050.37	***	85590.50	***
5.73	***	7.10	***	7.45	***	7.76	***	3.05	***
824964.45	***	779841.77	***	743429.86	***	714419.44	***	586737.92	***
1658.30	***	1566.16	***	1494.94	***	1436.61	***	1384.95	***
1807.62	***	1805.16	***	1712.50	***	1636.27	***	1571.05	***
0.05	***	0.05	***	0.05	***	0.05	***	0.05	***
97814.93	***	88135.51	***	81362.49	***	75953.73	***	71417.53	***
7.63	***	8.02	***	8.33	***	8.62	***	8.88	***
740001.90	***	705586.40	***	677252.37	***	654614.59	***	634440.32	***
1488.11	***	1413.68	***	1352.97	***	1316.75	***	1275.72	***
1695.31	***	1610.36	***	1539.37	***	1482.29	***	1432.13	***
0.10	***	0.10	***	0.10	***	0.10	***	0.10	***
80877.84	***	73664.33	***	68663.92	***	64663.23	***	61271.39	***
8.56	***	8.92	***	9.20	***	9.47	***	9.72	***
684824.21	***	655666.60	***	631697.62	***	612603.08	***	595570.10	***
1377.12	***	1312.46	***	1270.67	***	1231.87	***	1197.52	***
1551.85	***	1479.76	***	1421.79	***	1374.12	***	1332.68	***
0.15	***	0.15	***	0.15	***	0.15	***	0.15	***
69117.87	***	63244.03	***	59393.30	***	56399.51	***	53650.26	***
9.49	***	9.80	***	10.03	***	10.33	***	10.56	***
646951.85	***	619927.16	***	599717.52	***	581472.34	***	566370.14	***
1299.15	***	1246.60	***	1203.95	***	1163.27	***	1139.90	***
1445.02	***	1736.10	***	1335.26	***	1293.97	***	1257.57	***
0.20	***	0.20	***	0.20	***	0.20	***	0.20	***
58257.77	***	55405.39	***	52325.22	***	49875.89	***	47714.92	***
10.41	***	10.70	***	10.96	***	11.15	***	11.35	***
617345.45	***	593045.86	***	573430.71	***	557479.90	***	543630.98	***
[illegible]	***	1192.54	***	1153.10	***	1121.02	***	1093.17	***
[illegible]	***	1315.66	***	1265.62	***	1272.20	***	1199.80	***
0.25	***	0.25	***	0.25	***	0.25	***	0.25	***
52464.39	***	49297.16	***	46766.52	***	44703.28	***	42952.02	***
11.34	***	11.60	***	11.84	***	12.04	***	12.23	***
595214.97	***	572092.53	***	553515.90	***	539423.09	***	525421.93	***
1195.92	***	1150.41	***	1113.06	***	1082.70	***	1055.56	***
1714.15	***	1260.75	***	1217.94	***	1183.13	***	1153.21	***

ORIGINAL PAGE IS
OF POOR QUALITY

0.0000	0	0.0000	0	0.0000	0	0.0000	0
449.4000	1	459.8300	1	471.6300	1	481.5000	1
755.0000	2	743.1000	2	731.6000	2	720.5000	2
0.6487	3	0.6536	3	0.5720	3	0.5325	3
0.9147	4	0.7935	4	0.7734	4	0.7545	4
109.3700	5	109.3700	5	109.3700	5	109.3700	5
1013.2000	6	1213.2000	6	1013.2000	6	1013.2000	6
0.2000	7	0.2000	7	0.2000	7	0.2000	7
1.6355	8	1.5955	8	1.6355	8	1.6855	8
0.0161	9	0.0161	9	0.0161	9	0.0161	9
500.0000	A	550.0000	A	600.0000	A	650.0000	A
0.6000	B	0.6000	B	0.6000	B	0.6000	B
3.0000	C	3.0000	C	3.0000	C	3.0000	C
67.9700	D	67.9700	D	67.9700	D	67.9700	D
104.3752	E	104.3752	E	104.3752	E	104.3752	E
0.0163	I	0.0163	I	0.0163	I	0.0163	I

0.00	***	0.00	***	0.00	***	0.00	***
80360.60	***	75934.09	***	72223.52	***	68644.13	***
8.31	***	8.56	***	8.79	***	9.00	***
667855.18	***	649691.59	***	632761.84	***	517906.20	***
1342.97	***	1306.43	***	1272.40	***	1242.53	***
1518.97	***	1472.22	***	1429.35	***	1392.96	***

0.05	***	0.05	***	0.05	***	0.05	***
67679.43	***	64481.34	***	61613.91	***	59126.93	***
9.13	***	9.36	***	9.57	***	9.77	***
617850.80	***	603363.05	***	589734.81	***	577747.63	***
1242.42	***	1213.29	***	1185.98	***	1161.78	***
1390.89	***	1355.01	***	1321.55	***	1292.17	***

0.10	***	0.10	***	0.10	***	0.10	***
58455.04	***	55870.54	***	53642.50	***	51527.43	***
9.95	***	10.16	***	10.36	***	10.54	***
581477.17	***	569185.29	***	557559.17	***	547368.76	***
1169.28	***	1144.56	***	1121.20	***	1100.69	***
1298.37	***	1268.52	***	1240.51	***	1215.93	***

0.15	***	0.15	***	0.15	***	0.15	***
51443.52	***	49538.17	***	47903.33	***	46290.80	***
10.77	***	10.96	***	11.14	***	11.31	***
553829.76	***	542928.02	***	532613.18	***	523594.93	***
1113.68	***	1091.76	***	1071.02	***	1052.66	***
1228.05	***	1202.07	***	1177.63	***	1156.24	***

0.20	***	0.20	***	0.20	***	0.20	***
45933.88	***	44334.13	***	42930.77	***	41758.16	***
11.58	***	11.76	***	11.93	***	12.08	***
532103.75	***	522123.85	***	512687.16	***	504458.83	***
1069.99	***	1049.92	***	1030.95	***	1014.40	***
1172.80	***	1149.42	***	1127.43	***	1108.23	***

0.25	***	0.25	***	0.25	***	0.25	***
41490.24	***	40217.98	***	39054.58	***	38023.97	***
12.40	***	12.56	***	12.71	***	12.85	***
514581.61	***	505233.84	***	496409.61	***	485744.26	***
1034.76	***	1015.96	***	998.22	***	982.80	***
1128.23	***	1106.68	***	1086.42	***	1068.79	***

MIXED PHASE EXPANDER OPERATION

ORIGINAL PAGE IS OF POOR QUALITY

Assume 1000 kW expander output, Steam Tables properties, conditions A thru E and inlet quality x_1
Calculate flowrates

			0.0000	0	0.0000	0	0.0000	0	0.0000	0
1	h_{1f}		250.2900	1	298.4000	1	330.5100	1	355.3600	1
2	h_{1fg}		924.0000	2	888.8000	2	863.6000	2	843.0000	2
3	s_{1f}		0.4110	3	0.4740	3	0.5138	3	0.5435	3
4	s_{1fg}		1.2474	4	1.1286	4	1.0556	4	1.0016	4
5	h_{2f}		180.0700	5	180.0700	5	180.0700	5	180.0700	5
6	h_{2fg}		970.3000	6	970.3000	6	970.3000	6	970.3000	6
7	s_{2f}		0.3120	7	0.3120	7	0.3120	7	0.3120	7
8	s_{2fg}		1.4445	8	1.4446	8	1.4446	8	1.4446	8
9	v_3		0.0161	9	0.0161	9	0.0161	9	0.0161	9
A	P_1	psia	50.0000	A	100.0000	A	150.0000	A	200.0000	A
B	η_e		0.7000	B	0.7000	B	0.7000	B	0.7000	B
C	P_2	psia	14.6960	C	14.6960	C	14.6960	C	14.6960	C
D	h_3	$[t_3=100°F]$	67.9700	D	67.9700	D	67.9700	D	67.9700	D
E	h_4	$[t_4=207°F]$	175.0350	E	175.0350	E	175.0350	E	175.0350	E
I	v_4		0.0167	I	0.0167	I	0.0167	I	0.0167	I

x_1		0.00	***	0.00	***	0.00	***	0.00	***
$\dot{m}_e$	lb/h	1387453.71	***	512217.31	***	327712.11	***	246275.15	***
$\dot{m}_3/\dot{m}_e$		0.69	***	1.09	***	1.35	***	1.55	***
$\dot{m}_3$	lb/h	357953.61	***	558321.75	***	443430.17	***	382913.62	***
$\dot{m}_3$	gpm	1656.12	***	1122.71	***	551.68	***	770.80	***
$\dot{m}_4$	gpm	4327.25	***	2235.12	***	1663.71	***	1329.38	***
		0.05	***	0.05	***	0.05	***	0.05	***
		622577.32	***	303663.85	***	215453.57	***	173365.22	***
		1.08	***	1.46	***	1.71	***	1.89	***
		677168.96	***	444062.29	***	367571.42	***	328031.50	***
		1353.66	***	892.95	***	733.94	***	655.71	***
		2694.34	***	1554.85	***	1313.29	***	1032.26	***
		0.10	***	0.10	***	0.10	***	0.10	***
		401633.85	***	215799.40	***	160626.62	***	132453.32	***
		1.48	***	1.83	***	2.06	***	2.23	***
		596297.55	***	395921.56	***	330542.45	***	295511.79	***
		1199.28	***	796.15	***	665.43	***	594.24	***
		2075.14	***	1372.04	***	1022.13	***	839.54	***
		0.15	***	0.15	***	0.15	***	0.15	***
		296443.98	***	167372.92	***	128027.32	***	107595.93	***
		1.89	***	2.21	***	2.41	***	2.57	***
		559692.59	***	369388.88	***	308940.41	***	276418.15	***
		1125.47	***	742.79	***	621.24	***	555.64	***
		1730.28	***	1116.16	***	903.65	***	758.53	***
		0.20	***	0.20	***	0.20	***	0.20	***
		234916.76	***	136694.76	***	106427.72	***	90531.39	***
		2.29	***	2.58	***	2.77	***	2.91	***
		536282.27	***	352582.16	***	294353.67	***	263355.66	***
		1082.42	***	709.00	***	591.97	***	529.55	***
		1597.82	***	1017.42	***	832.42	***	725.82	***
		0.25	***	0.25	***	0.25	***	0.25	***
		194539.80	***	115521.63	***	91064.20	***	73338.31	***
		2.69	***	2.95	***	3.12	***	3.25	***
		524231.81	***	340991.94	***	287995.41	***	253655.39	***
		1054.16	***	685.67	***	571.06	***	510.49	***
		1494.64	***	949.27	***	779.91	***	692.57	***

ORIGINAL PAGE IS
OF POOR QUALITY

0.0000	0	0.0000	0	0.0000	0	0.0000	0	0.0000	0
376.0000	1	393.8400	1	433.5500	1	424.3000	1	437.2000	1
825.1200	2	989.0000	2	734.2000	2	756.5000	2	767.4000	2
0.5575	3	0.5879	3	0.6055	3	0.6214	3	0.6356	3
0.3333	4	0.9225	4	0.3910	4	0.8638	4	0.8378	4
180.3700	5	180.0700	5	180.0700	5	180.0700	5	180.0700	5
970.3000	6	970.3000	6	970.3000	6	970.3000	6	970.3000	6
0.3120	7	0.3120	7	0.3120	7	0.3120	7	0.3120	7
1.4446	8	1.4446	8	1.4446	8	1.4446	8	1.4446	8
0.0161	9	0.0161	9	0.0161	9	0.2161	9	0.0161	9
250.0000	A	300.0000	A	350.0000	A	400.0000	A	450.0000	A
0.7000	B	0.7000	B	0.7000	B	0.7000	B	0.7000	B
14.5960	C	14.6960	C	14.6960	C	14.5960	C	14.6960	C
67.9700	D	67.9700	D	67.9700	D	67.9700	D	67.9700	D
175.0350	E	175.0350	E	175.0350	E	175.0350	E	175.0350	E
0.0167	I	0.0167	I	0.0167	I	0.0167	I	0.0167	I
0.00	***	0.00	***	0.00	***	0.00	***	0.00	***
200583.61	***	171347.06	***	150483.18	***	135905.53	***	122578.22	***
1.72	***	1.86	***	1.96	***	2.09	***	2.13	***
344474.93	***	318296.21	***	297772.51	***	282066.02	***	269273.65	***
692.70	***	646.06	***	598.75	***	567.20	***	539.46	***
1133.25	***	1016.19	***	931.56	***	867.28	***	812.75	***
0.05	***	0.05	***	0.05	***	0.05	***	0.05	***
146100.65	***	128564.59	***	115528.68	***	105634.64	***	97494.91	***
2.04	***	2.17	***	2.29	***	2.39	***	2.48	***
298655.03	***	279437.85	***	264176.21	***	252264.71	***	241793.62	***
600.56	***	561.91	***	531.22	***	507.27	***	486.22	***
924.84	***	843.42	***	789.57	***	744.23	***	705.53	***
0.10	***	0.10	***	0.10	***	0.10	***	0.10	***
114319.48	***	102877.75	***	93751.30	***	86758.54	***	80933.42	***
2.37	***	2.49	***	2.59	***	2.69	***	2.77	***
272393.16	***	256105.88	***	243226.57	***	233113.33	***	224309.92	***
547.75	***	515.00	***	489.10	***	468.76	***	451.06	***
805.39	***	746.48	***	700.79	***	665.16	***	634.74	***
0.15	***	0.15	***	0.15	***	0.15	***	0.15	***
94706.78	***	85745.95	***	78923.37	***	73635.75	***	69121.54	***
2.70	***	2.81	***	2.90	***	2.99	***	3.06	***
255369.47	***	240544.65	***	228918.09	***	219769.75	***	211903.65	***
513.52	***	483.70	***	460.33	***	441.93	***	426.11	***
727.96	***	678.50	***	640.14	***	610.06	***	584.58	***
0.20	***	0.20	***	0.20	***	0.20	***	0.20	***
80540.34	***	73505.40	***	68130.55	***	63915.95	***	60405.77	***
3.02	***	3.12	***	3.21	***	3.28	***	3.35	***
243438.46	***	229426.27	***	218521.73	***	209938.95	***	202643.44	***
489.52	***	461.35	***	439.43	***	422.16	***	407.49	***
673.72	***	625.93	***	595.08	***	565.46	***	547.00	***
0.25	***	0.25	***	0.25	***	0.25	***	0.25	***
70061.29	***	64323.05	***	59974.12	***	56480.58	***	53512.11	***
3.35	***	3.44	***	3.51	***	3.58	***	3.65	***
234612.26	***	221085.72	***	210626.84	***	202395.39	***	195467.26	***
471.78	***	444.58	***	423.54	***	406.39	***	393.06	***
633.55	***	593.49	***	562.62	***	536.32	***	517.95	***

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0.0000	0	0.0000	0	0.0000	0	0.0000	0
449.4000	1	460.9000	1	471.5000	1	481.3000	1
755.0000	2	743.1000	2	731.6000	2	720.5000	2
0.6487	3	0.6602	3	0.6720	3	0.6325	3
0.5147	4	0.7575	4	0.7734	4	0.7543	4
160.0700	5	160.0700	5	180.0700	5	190.0700	5
970.3000	6	970.3000	6	970.3000	6	970.3000	6
0.3120	7	0.3120	7	0.3120	7	0.3120	7
1.4446	8	1.4446	8	1.4446	8	1.4446	8
0.0161	9	0.0161	9	0.0161	9	0.0161	9
500.0000	A	550.0000	A	600.0000	A	650.0000	A
0.7000	B	0.7000	B	0.7000	B	0.7000	B
14.6960	C	14.6960	C	14.6960	C	14.6960	C
67.9700	D	67.9700	D	67.9700	D	67.9700	D
175.0350	E	175.0350	E	175.0350	E	175.0350	E
0.0167	I	0.0167	I	0.0167	I	0.0167	I
0.00	***	0.00	***	0.00	***	0.00	***
112922.77	***	104850.71	***	98042.30	***	91211.75	***
2.23	***	2.37	***	2.44	***	2.52	***
257433.29	***	248063.23	***	239712.72	***	232331.04	***
517.86	***	496.87	***	482.03	***	467.19	***
778.27	***	733.99	***	702.35	***	674.57	***
0.05	***	0.05	***	0.05	***	0.05	***
91621.21	***	85551.19	***	80812.32	***	75721.43	***
2.56	***	2.64	***	2.72	***	2.79	***
237466.45	***	225154.12	***	219578.35	***	217761.16	***
469.47	***	454.77	***	441.55	***	429.65	***
674.75	***	646.17	***	624.55	***	584.04	***
0.10	***	0.10	***	0.10	***	0.10	***
76235.26	***	72233.02	***	68729.95	***	65686.61	***
2.85	***	2.92	***	2.39	***	3.05	***
217242.32	***	211052.22	***	205465.65	***	200533.68	***
436.85	***	424.40	***	413.17	***	403.25	***
610.27	***	589.07	***	570.17	***	553.59	***
0.15	***	0.15	***	0.15	***	0.15	***
65581.81	***	62503.89	***	59750.57	***	57425.32	***
3.13	***	3.20	***	3.26	***	3.32	***
205552.65	***	200016.91	***	195023.65	***	190631.70	***
413.34	***	402.21	***	392.17	***	383.34	***
563.81	***	545.96	***	525.87	***	515.82	***
0.20	***	0.20	***	0.20	***	0.20	***
57540.81	***	55032.96	***	52506.55	***	51012.42	***
3.42	***	3.45	***	3.53	***	3.59	***
196729.52	***	191605.21	***	186585.32	***	182942.26	***
395.60	***	385.29	***	376.00	***	367.87	***
526.74	***	512.37	***	498.85	***	466.43	***
0.25	***	0.25	***	0.25	***	0.25	***
51256.27	***	49237.77	***	47447.92	***	45856.92	***
3.70	***	3.76	***	3.61	***	3.25	***
189633.70	***	184577.16	***	180606.32	***	176795.03	***
381.73	***	371.97	***	363.18	***	355.52	***
501.33	***	467.04	***	474.23	***	462.25	***

MIXED PHASE EXPANDER OPERATION

Assume 1000 kW expander output, Steam Tables properties, conditions A thru E and inlet quality x_1
Calculate flowrates

			0.0000	0	0.0000	0	0.0000	0	0.0000	0
1	h_{1f}		250.0900	1	298.4000	1	330.5100	1	355.3600	1
2	h_{1fg}		924.0000	2	888.8000	2	863.6000	2	843.2000	2
3	s_{1f}		0.4110	3	0.4740	3	0.5139	3	0.5435	3
4	s_{1fg}		1.2474	4	1.1286	4	1.0575	4	1.0015	4
5	h_{2f}		109.3700	5	109.3700	5	109.3700	5	109.3700	5
6	h_{2fg}		1013.2000	6	1013.2000	6	1013.2000	6	1013.2000	6
7	s_{2f}		0.2008	7	0.2008	7	0.2008	7	0.2008	7
8	s_{2fg}		1.6855	8	1.6855	8	1.6855	8	1.6855	8
9	v_3		0.0161	9	0.0161	9	0.0161	9	0.0161	9
A	p_1	psia	50.0000	A	100.0000	A	150.0000	A	200.0000	A
B	η_e		0.7000	B	0.7000	B	0.7000	B	0.7000	B
C	p_2	psia	3.0000	C	3.0000	C	3.0000	C	3.0000	C
D	h_3	[t_3=100°F]	67.9700	D	67.9700	D	57.9700	D	67.9700	D
E	h_4	[t_4=136.48°F]	104.3752	E	104.3752	E	104.3752	E	104.3752	E
I	v_4		0.0163	I	0.0163	I	0.0153	I	0.0163	I
	x_1		0.00	***	0.00	***	0.00	***	0.00	***
	$\dot{m}_e$	lb/h	339452.77	***	195525.28	***	147606.40	***	121942.59	***
	$\dot{m}_3/\dot{m}_e$		3.73	***	4.85	***	5.58	***	6.13	***
	$\dot{m}_3$	lb/h	1264975.49	***	952968.63	***	824364.92	***	746946.48	***
	$\dot{m}_3$	gpm	2542.71	***	1916.31	***	1657.59	***	1502.01	***
	$\dot{m}_4$	gpm	3255.28	***	2334.39	***	1972.46	***	1762.91	***
			0.05	***	0.05	***	0.05	***	0.05	***
			211377.55	***	138042.39	***	103715.36	***	93721.96	***
			4.83	***	5.97	***	6.54	***	7.05	***
			1020343.38	***	810467.85	***	[illegible]	***	660098.58	***
			2051.78	***	1629.75	***	1447.59	***	1328.95	***
			2438.39	***	1924.46	***	[illegible]	***	1531.87	***
			0.10	***	0.10	***	0.10	***	0.10	***
			153429.40	***	106765.51	***	97234.23	***	76108.46	***
			5.93	***	6.89	***	7.51	***	7.98	***
			909775.35	***	732923.80	***	655951.02	***	627153.23	***
			1829.44	***	1473.62	***	1317.22	***	1220.95	***
			2157.16	***	1702.65	***	1506.04	***	1366.37	***
			0.15	***	0.15	***	0.15	***	0.15	***
			122429.26	***	86514.49	***	72399.40	***	64067.90	***
			7.03	***	7.91	***	8.47	***	8.90	***
			846769.70	***	684162.39	***	613563.85	***	578480.47	***
			1702.75	***	1375.76	***	1233.94	***	1147.16	***
			1962.77	***	1563.65	***	1391.81	***	1287.45	***
			0.20	***	0.20	***	0.20	***	0.20	***
			99112.33	***	72967.24	***	61875.76	***	55316.69	***
			8.13	***	8.93	***	9.44	***	9.93	***
			806068.72	***	650806.20	***	564170.49	***	543797.11	***
			1620.90	***	1308.69	***	1174.59	***	1093.51	***
			1836.54	***	1468.36	***	1310.78	***	1215.56	***
			0.25	***	0.25	***	0.25	***	0.25	***
			84207.03	***	62599.53	***	54024.73	***	43668.07	***
			9.23	***	9.94	***	10.41	***	10.76	***
			777609.61	***	626520.16	***	562222.12	***	523527.22	***
			1563.67	***	1259.85	***	1130.56	***	1052.75	***
			1748.56	***	1398.96	***	1250.32	***	1160.94	***

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0.0000	0	0.0000	0	0.0000	0	0.0000	0	0.0000	0
376.0000	1	353.6400	1	423.5900	1	424.0000	1	477.2000	1
825.1000	2	605.2000	2	734.2000	2	720.5000	2	757.4200	2
1.5675	3	0.5375	3	0.7256	3	0.6214	3	0.6356	3
0.5500	4	0.9225	4	0.9916	4	0.8630	4	0.8372	4
109.3700	5	109.3700	5	109.3700	5	109.3700	5	109.3700	5
1013.2000	6	1013.2000	6	1013.2000	6	1013.2000	6	1013.2000	6
0.2008	7	0.2008	7	0.2008	7	0.2008	7	0.2006	7
1.6555	8	1.6555	8	1.6855	8	1.5855	8	1.5855	8
0.0161	9	0.0161	9	0.0151	9	0.0161	9	0.0151	9
250.0000	A	302.0000	A	350.0000	A	400.0000	A	450.0000	A
0.7000	B	0.7000	B	0.7000	B	0.7000	B	0.7800	B
3.0000	C	3.0000	C	3.0000	C	3.0000	C	3.0000	C
67.2700	D	67.9700	D	67.9700	D	67.9700	D	67.9700	D
104.3752	E	104.3752	E	104.3752	E	104.3752	E	104.3752	E
0.0153	I	0.0163	I	0.0153	I	0.0163	I	0.0163	I

0.00	***	0.00	***	0.00	***	0.00	***	0.00	***
105542.63	***	94177.69	***	85563.34	***	73902.32	***	73363.29	***
6.57	***	6.36	***	7.29	***	7.59	***	7.96	***
597719.46	***	655042.89	***	623332.59	***	591566.62	***	576957.99	***
1394.98	***	1317.21	***	1254.45	***	1204.45	***	1160.18	***
1621.64	***	1520.10	***	1439.31	***	1375.34	***	1315.44	***

0.05	***	0.05	***	0.05	***	0.05	***	0.05	***
83155.65	***	75596.41	***	65735.27	***	65111.76	***	61215.28	***
7.47	***	7.82	***	8.13	***	5.41	***	8.66	***
620922.15	***	591326.67	***	567193.12	***	547705.31	***	530417.08	***
1248.59	***	1193.05	***	1140.55	***	1101.37	***	1065.53	***
1428.53	***	1353.14	***	1292.29	***	1243.35	***	1208.37	***

0.10	***	0.10	***	0.10	***	0.10	***	0.10	***
68603.86	***	63140.35	***	59354.72	***	55425.63	***	52513.84	***
8.36	***	8.65	***	8.98	***	9.23	***	9.47	***
577593.79	***	548577.34	***	528273.63	***	511635.45	***	497095.75	***
1153.44	***	1103.15	***	1068.21	***	1028.95	***	939.60	***
1302.98	***	1241.19	***	1191.16	***	1150.65	***	1115.13	***

0.15	***	0.15	***	0.15	***	0.15	***	0.15	***
58326.54	***	54055.15	***	50909.06	***	48249.15	***	45935.34	***
9.26	***	9.55	***	9.62	***	10.05	***	10.27	***
542774.49	***	517977.23	***	499753.54	***	485011.95	***	472067.22	***
1096.62	***	1041.58	***	1025.02	***	975.70	***	949.27	***
1214.84	***	1160.92	***	1117.33	***	1091.34	***	1051.09	***

0.20	***	0.20	***	0.20	***	0.20	***	0.20	***
53915.39	***	47491.19	***	44853.62	***	42716.47	***	40898.50	***
10.15	***	10.42	***	10.65	***	10.97	***	11.07	***
515762.94	***	494932.11	***	478119.13	***	464447.61	***	452576.51	***
1037.13	***	995.25	***	961.44	***	933.94	***	910.07	***
1149.55	***	1100.54	***	1061.07	***	1029.00	***	1001.22	***

0.25	***	0.25	***	0.25	***	0.25	***	0.25	***
44956.62	***	42254.71	***	40035.59	***	35322.75	***	36824.59	***
11.04	***	11.29	***	11.52	***	11.69	***	11.97	***
496759.84	***	476572.12	***	461052.79	***	448112.60	***	436968.75	***
999.00	***	959.13	***	927.12	***	901.12	***	878.69	***
1099.24	***	1053.47	***	1016.77	***	986.94	***	961.29	***

ORIGINAL PAGE IS OF POOR QUALITY

0.0000	0	0.2000	0	0.0000	0	0.2000	0
449.4000	1	460.9000	1	471.6000	1	481.9000	1
755.0000	2	743.1000	2	731.5000	2	720.5000	2
0.5487	3	0.5606	3	0.5720	3	0.5825	3
0.8147	4	0.7935	4	0.7734	4	0.7546	4
109.3700	5	109.3700	5	109.3700	5	109.3700	5
1013.2000	6	1013.2000	6	1013.2000	6	1013.2000	6
0.2000	7	0.2000	7	0.2000	7	0.2000	7
1.6855	8	1.6855	8	1.6855	8	1.6855	8
0.0161	9	0.0151	9	0.0151	9	0.0151	9
500.0000	A	550.0000	A	600.0000	A	650.0000	A
0.7000	B	0.7000	B	0.7000	B	0.7000	B
3.0000	C	3.0000	C	3.0000	C	3.0000	C
67.9700	D	67.9700	D	67.9700	D	67.9700	D
104.3752	E	104.3752	E	104.3752	E	104.3752	E
0.0163	I	0.0163	I	0.0163	I	0.0163	I
0.00	***	0.00	***	0.00	***	0.00	***
68980.52	***	65086.36	***	61774.44	***	58837.83	***
8.12	***	8.35	***	8.57	***	8.77	***
559054.39	***	543477.12	***	529574.78	***	516242.98	***
1124.19	***	1092.86	***	1057.70	***	1035.10	***
1274.23	***	1234.73	***	1198.56	***	1165.79	***
0.05	***	0.05	***	0.05	***	0.05	***
58010.94	***	55259.72	***	52817.06	***	50680.23	***
8.90	***	9.11	***	9.32	***	9.51	***
516193.50	***	503775.43	***	492054.67	***	481019.35	***
1078.00	***	1013.23	***	999.54	***	969.88	***
1165.02	***	1134.26	***	1105.50	***	1098.40	***
0.10	***	0.10	***	0.10	***	0.10	***
50104.32	***	48026.18	***	46153.71	***	44509.22	***
9.68	***	9.88	***	10.07	***	10.24	***
485016.09	***	474480.20	***	464523.52	***	455728.72	***
975.31	***	954.12	***	934.10	***	916.52	***
1065.72	***	1060.13	***	1036.12	***	1015.05	***
0.15	***	0.15	***	0.15	***	0.15	***
44034.45	***	42461.29	***	40978.57	***	39677.30	***
10.46	***	10.64	***	10.81	***	10.97	***
461717.97	***	451973.97	***	443132.68	***	435794.16	***
927.65	***	908.86	***	891.06	***	875.53	***
1025.44	***	1003.17	***	982.23	***	963.89	***
0.20	***	0.20	***	0.20	***	0.20	***
39371.90	***	38052.11	***	36848.80	***	35732.72	***
11.24	***	11.41	***	11.56	***	11.71	***
442696.03	***	434141.32	***	426053.23	***	419000.30	***
890.21	***	873.00	***	856.74	***	842.56	***
978.00	***	958.05	***	939.19	***	922.74	***
0.25	***	0.25	***	0.25	***	0.25	***
35563.07	***	34472.43	***	33475.35	***	32600.55	***
12.03	***	12.17	***	12.31	***	12.44	***
427677.05	***	419664.67	***	412181.04	***	405530.74	***
860.80	***	843.09	***	826.68	***	815.47	***
939.08	***	921.41	***	904.04	***	886.94	***

APPENDIX I

TEST MATRIX (PROPOSED)

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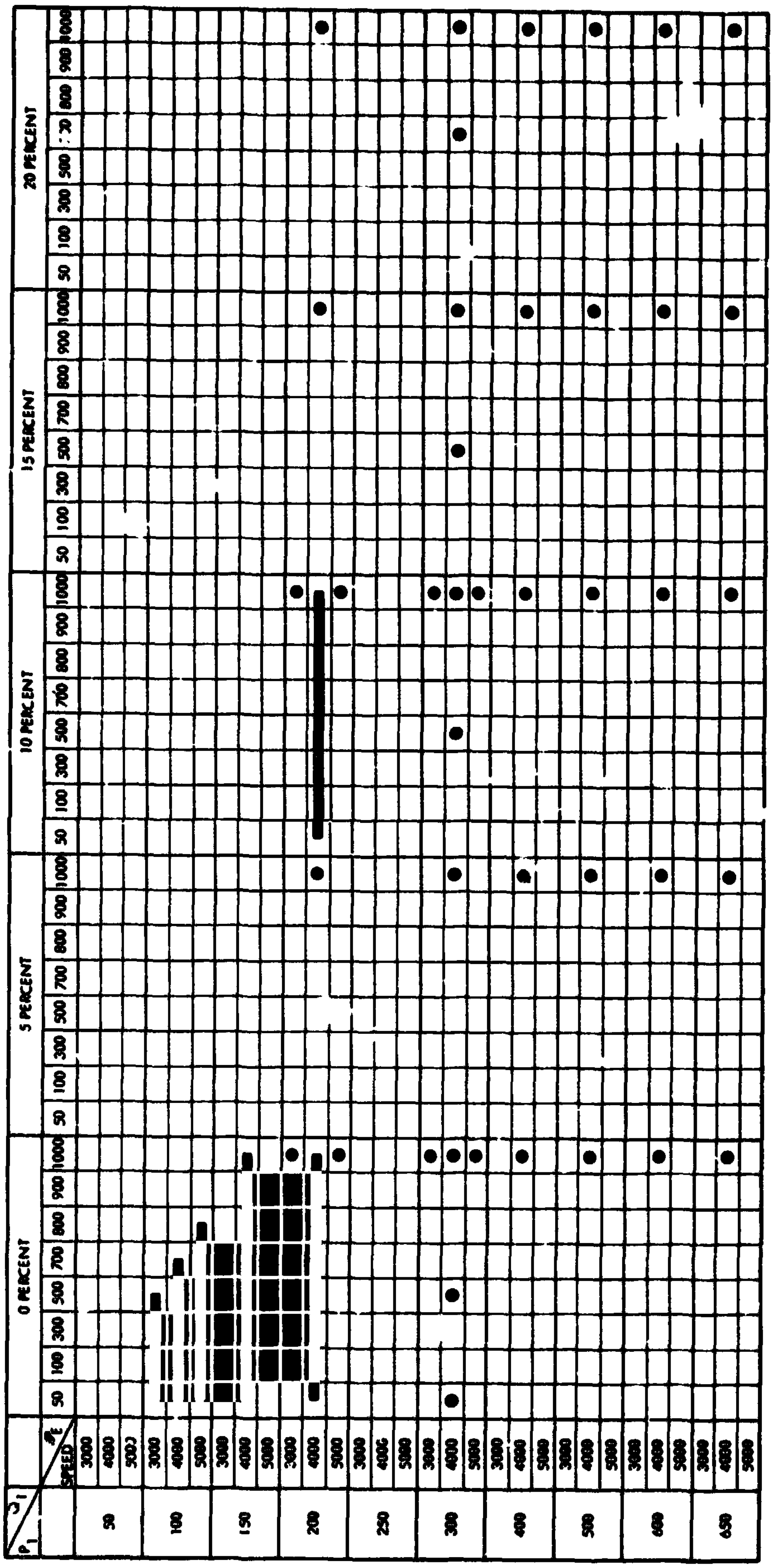
Test Matrix



P_1 INLET PRESSURE (PSIA)

Q_1 INLET STEAM QUALITY (%)

$\mathscr{P}_E$ ELECTRIC LOAD (KW)

SPEED ROTOR SPEED (RPM)

APPENDIX J

ORIFICE FLOW METERS

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APPENDIX J

ORIFICE FLOW METERS

The length and tolerance of the orifice meter tubes complied with the specifications given in the American Gas Association Gas Measurement Committee Report No. 3, and in the ASME Fluid Meters Reference Book Parts 1 and 2.

Steam

The orifice meter constants were from Orifice Meter Constants Handbook No. 2, revised to conform with A.G.A. Report No. 3 by H. V. Beck, Chief Engineer, American Meter Company.

Liquid

The flow of liquid was determined by the following equation.

$$\dot{m} = \frac{C\,a\,F_a\,\eta}{1 - \beta^4}\sqrt{2gh} \qquad (1)$$

With the units in American practice the equation can be written:

$$\dot{m} = 359\ K\ d^2\ F_a\ \sqrt{h_w\,\rho} \qquad (2)$$

Where $\dot{m}$ = rate of flow, lb/h

K = flow coefficient

a = orifice area, in.^{2}

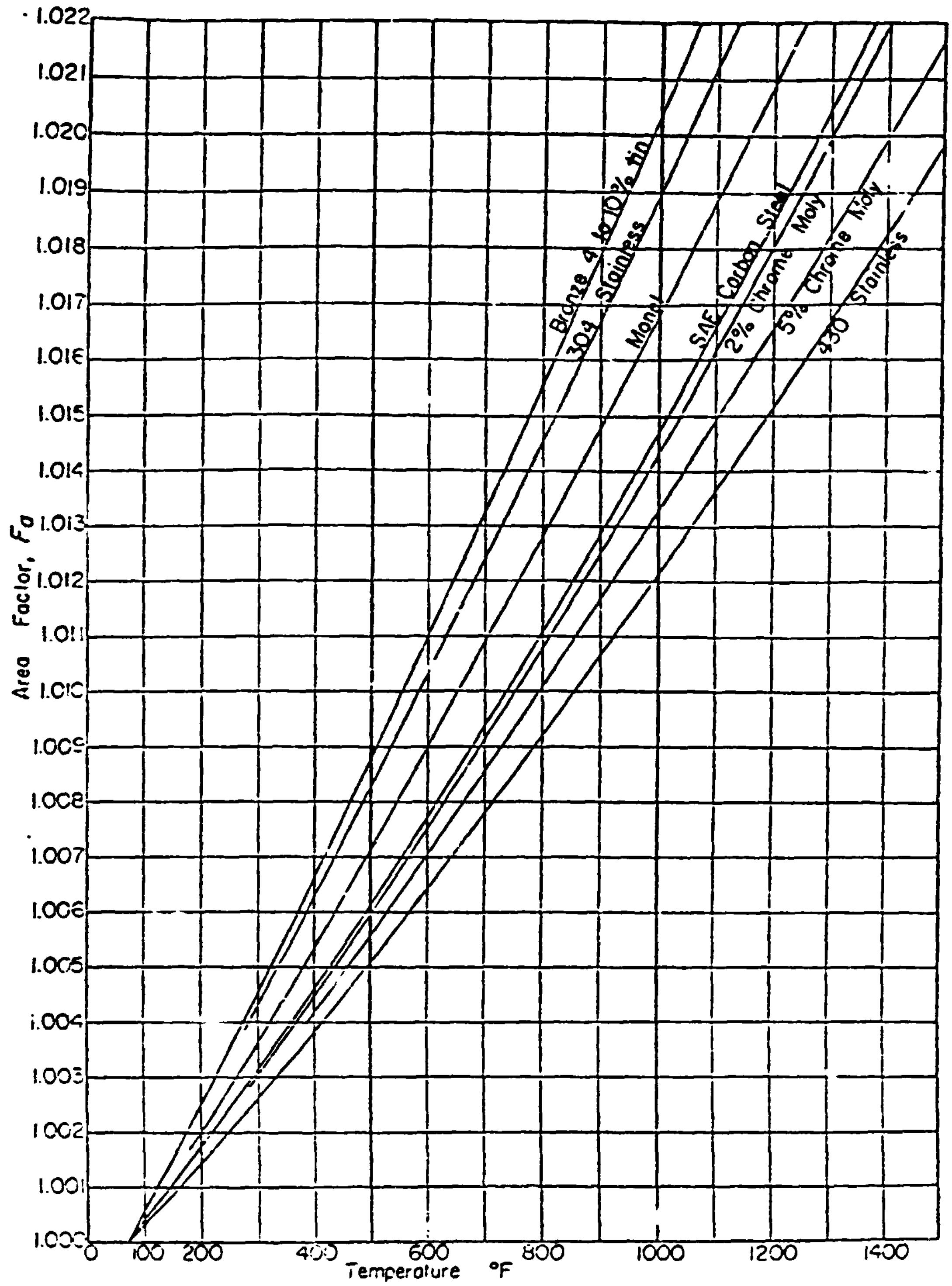
d = orifice diameter, in.

D	= pipe inside diameter in.
β	= diameter ratio, d/D
h	= differential pressure
h_w	= differential pressure, inches of 68 F H_2O
ρ	= density of flowing fluid at the inlet of the orifice, lb/ft^3
F_a	= thermal expansion factor of the orifice plate from Figure A

For the meter tube with flange pressure taps located in the conventional 1-in. position, the equation for computing the flow coefficient is

$$K = 0.5980 + 0.468\ (\beta^4 + 10\,\beta^{12}) = (0.00087 + 0.0081\,\beta^4)\ . \qquad (3)$$

where R_D is the Reynolds number based on the pipe inside diameter. Equation (3) is applicable for D of 1-1/2 in. or greater, β between 0.15 and 0.7, and R_D greater than 1000.



NOTE: The use of bronze in the piping is restricted to temperatures below 406 F.

FIGURE A: Area Factor (F_a) for Orifice Flow Coefficient Equation from ASME Power Test Codes

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APPENDIX K

ACCEPTANCE AND INTERFACE TESTING

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R.A. McKay
Final Draft

ACCEPTANCE AND INTERFACE TESTING

A. PURPOSES

1. To verify that the HPC Power System 76-1 (a) complies with the contract specifications as embodied in Contract 954404, Exhibit 1, and HPC Drawings B13 and B14, (b) is a complete and functioning subsystem in compliance with HPC Drawing B20, and (c) is ready for delivery to JPL.
2. To verify that the interfaces between the HPC Power System 76-1 and the JPL support system are correct and to demonstrate that the Power System and the JPL Control and Instrument Support Van function together as a system.

B. APPROACH

1. HPC assemble, prepare, and check the Power System in Mission Viejo. The preparation should include:
   a. Preset vibration switches (V_1, V_2) to NC (normally closed) plus margin at rest. V_1 _____ V_2 _____
   b. Preset underspeed switch (US) to NO (normally open) at $\sim \leq 50$ Hz. _____
   c. Preset high oil temperature (OHT) switch to NC ≤ 150°F. _____
   d. Preset low oil pressure (LOP) switch to NO $\leq$10-12 psig. _____
   e. Preset shaft seal pressure (SSP) switch to NO ≤ 125 psig. _____
   f. Preset overspeed (OS) switch to NC ≤ 2200 RPM = 66 Hz. _____
   g. Preset Stop (S) rate for Automatic Stop valve. _____
   h. Preset Stop (S) rate for Governor Override. _____
   i. Preset Emergency Stop (ES) rate for Automatic Stop valve. _____
   j. Preset Emergency Stop (ES) rate for Governor Override. _____
2. JPL assemble and check the Control and Instrument Support Van equipment and associated cables in Pasadena.

3. When both assemblies are ready, transport Van to Mission Viejo. Park along curb toward front of 25721 Obrero and order air compressors for driving Power System. Compressors will arrive in seven days. When they arrive they will park along Obrero toward rear of 25721.

4. During wait for compressors, JPL will interface with the Power Systems at the terminal strips TB"EA", TB"EB", and TB"EC" in the junction boxes as shown on HPC Drawing B20 . As part of the procedure of interfacing at the terminal strips, each function possible will be checked for end-to-end signal to verify that the JPL and HPC wiring diagrams are correct and correctly executed and that the nomenclature is mutually compatible. Static testing will then be carried out as described under Static Test Procedure, Section C, and the Power System will be checked against Exhibit 1 and HPC Drawings B13 and B14.

5. After the compressors arrive, the Dynamic Acceptance and Interface Testing will be performed as described under Dynamic Test Procedures, Sections D and E.

6. The Load Bank Interface Testing will not be included in Mission Viejo because of insufficient power. Also science data instrumentation testing for brine parameters, pressure, temperature, and flow rate will be postponed to the field, except that at least two unmounted temperature and pressure measuring devices will be wired and monitored.

ACCEPTANCE AND INTERFACE TESTING (Cont'd.)

C. STATIC TEST PROCEDURE

1. Check Batteries. _____
2. Jumper LOP switch. _____ Keep jumpered through step C-22.
3. Reset Emergency Stop relay to energize the safety shutdown circuit. _____
4. Verify that the Exciter switch is in Underspeed Bypass position. _____
5. Activate Data Logger and Intercoms. _____ _____ _____ Log SSP fault. _____
6. Operate pump #1 to prime lube oil system. _____
7. Operate pump #2. _____ At 125 psig monitor no fault. _____ Pressurize to 150 psig. _____ Verify that bearing and winding temperatures, bearing thrust, and throttle position are being logged. See check-list in Appendix.
8. Momentarily turn (key) Start switch. _____ Throttle should open. Observe. _____ Log. _____ Stop relay should reset. _____
9. Operate pump #3 to open Automatic Stop valve fully. _____
10. Press Stop button at power plant. _____ Observe Throttle[b] and Automatic Stop valve close slowly. _____ _____ Estimate closing time of Automatic Stop valve. _____ Log Throttle[b] position. _____
11. Momentarily turn Start switch. _____ Throttle[b] should open. Observe. _____ Log. _____ Stop relay should reset. _____

---

b - Throttle response must be verified. It may be necessary to monitor the Governor Override Stop relay instead.

_____ _____ _____ _____

Date: Test Staff:

Notes:

12. Press Stop button in Van. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Estimate closing time of Throttle. _____ Log Throttle[b] position. _____

13. Momentarily turn Start switch. _____ Throttle[b] should open and Stop relay should reset. _____ _____ Log Throttle[b] position. _____

14. Operate pump #3 to open Automatic Stop valve fully. _____

15. Press Emergency Stop button at power plant. _____ Observe Throttle[b] and Automatic Stop valve close rapidly. _____ _____ Estimate closing time of Automatic Stop valve. _____ Log Throttle[b] position. _____

16. Reset Emergency Stop relay. _____ Observe Throttle[b] open and Emergency Stop realy reset. _____ _____ Log Throttle[b] position. _____

17. Press Emergency Stop button in Van. _____ Observe Throttle[b] close and Emergency Stop relay trip. _____ _____ Estimate closing time of Throttle[b]. _____ Log Throttle[b] position. _____

18. Reset Emergency Stop relay. _____ Observe Throttle[b] open and Emergency Stop relay reset. _____ _____ Log Throttle[b] position. _____

19. Underset or otherwise trip vibration switch V_1. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log V_1 fault and Throttle[b] position. _____ _____ Reset V_1. _____ Log no fault. _____ Turn Start switch mentarily. _____ Throttle[b] should open and Stop relay should reset. _____ _____ Log Throttle[b] position. _____

---

b - Throttle response must be verified. It may be necessary to monitor the Governor Override Stop instead.

_____ _____ _____ _____

Date: Test Staff:

Notes:

20. Underset or otherwise trip Vibration switch V_2. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log V_2 fault and Throttle[b] position. _____ _____ Reset V_2. Log no fault. _____ Turn Start switch. Observe Throttle[b] open and Stop relay reset. _____ _____ Log Throttle[b] position. _____

21. Open OHT circuit. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log OHT fault and Throttle[b] position. _____ _____ Restore OHT circuit. _____ Turn Start switch. _____ Observe Throttle[b] open and Stop relay reset. _____ _____

22. Turn Exciter switch to On position to open US bypass. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log US fault and Throttle[b] position. _____ _____ Turn Exciter switch to US bypass. _____ Log no fault. _____ Turn Start switch. _____ Observe Throttle[b] open and Start relay reset. _____ _____ Log Throttle[b] position. _____

23. Remove jumper from LOP switch. _____ Observe Throttle[b] close and Stop relay trip. ____ . _____ Log LOP fault and Throttle[b] position. _____ _____

24. Open battery circuit by pressing Emergency Stop button. _____ Log all bearing and winding temperature data. _____ Refer to check-list in Appendix.

25. Turn off Data Logger. _____ Turn off Intercoms. _____ _____

---

b - Throttle response must be verified. It may be necessary to monitor the Governor Override Stop instead.

_________ _________ _________ _________

Date: Test Staff:

Notes:

Revised 12/01/77
For Test of 12/04/77

ACCEPTANCE AND INTERFACE TESTING (contd)

D. DYNAMIC TEST PROCEDURE: MODIFIED START, RUN, STOP

1. Install circuitry with auxiliary switches to permit bypassing the OS switch. ______ (This is accomplished by placing a switched jumper across the OS relay output and an auxiliary switch in the OS switch output circuit. The switched jumper requires two switches in series, one at the start station and one at the backup RPM monitor station.)

   Place a meter across the OS switch terminals. ______ Leave all three switches in closed (on) position. ______

2. Activate the data logger and intercoms. ______

3. Check for SSP fault ______, LOP fault ______, US fault ______, OS no fault ______.

4. Cpen auxiliary switch in OS switch circuit (near OS switch). ______ Log OS fault. ______

5. Jumper US and OS in Van. ______ Log US no fault ______ and OS no fault ______.

6. Inspect the Power Plant, Van, and Cables for readiness. ______ ______ Verifv that Main Circuit Breaker is open. ______ Set inhouse breaker off. ______ Record cumulative operating time. ______

7. Operate pump #1 to prime lube oil system. ______

Date: Test Staff:

Notes:

8. Open shaft guard #1. _______ Manually roll over power train. _______ Leave guard open to permit use of surface speed tachometer. _______

9. Check batteries. _______ Close battery switch. _______ Log SSP no fault. _______

10. Reset Emergency Stop relay to energize the safety shutdown circuit. _______

11. Verify that Exciter switch is in Underspeed Bypass position. _______

12. Verify that Automatic Stop and Manual 8" gate valves are closed. _______

13. Turn on compressors. _______ (Wear ear protection as necessary.)

14. Open Manual gate valve about 1/3. _______

15. Check nitrogen pressure. _______ Recharge if necessary. _______ Log engineering data. _______ See checklist in Appendix.

16. Hold Start switch on. _______ Observe Throttle open. _______

17. With Start switch still on, operate pump #3 to partly open Automatic Stop valve. _______ Rotation should start. _______ Watch Tachometer and drive fluid pressure. _______ _______ Watch oil pressure to bearings. _______ Release Start button slightly below LOP setpoint. _______ Observe Automatic Stop valve start to close slowly. Arrest with Start switch. _______ Log LOP fault. _______

18. With Start switch held on, operate pump #3 to partly open Automatic Stop valve. _______ Observe rotation. _______ Monitor Tachometer and drive fluid pressure. Monitor oil pressure to bearings. _______ Release Start button when oil pressure is above LOP setpoint. _______ Observe plant continue to run, throttled by Automatic Stop valve. _______ Log LOP no fault. _______ Observe US fault at plant. _______

Date: Test Staff:

Notes:

19. Verify that lube oil reservoir temperature is above 60°F. Otherwise, wait until it is. ______ Then continue to open Automatic Stop valve to bring plant to standard operating speed according to the following schedule.

   a. Male rotor 1500 RPM for 10 minutes (1/2 speed). Start time. ______ End time. ______

   b. Transfer control to governor at 1800 RPM. ______

   c. Adjust governor and automatic stop valve alternately to bring speed to 2500 RPM (50 Hz).

   d. Excite governor. ______ Bring speed to 2750 RPM. ______ (55 Hz)

   e. Turn on inhouse breaker. ______ Check operation of oil fan. ______

   f. With governor, slowly bring speed to 3000 RPM (60 Hz). ______ Run 10 minutes under governor control. Start time. ______ While running 10 minutes or more at normal speed, perform steps g through k.

   g. Adjust voltage at power plant to 480 V. ______ Check remote voltage adjustment capability. ______

   h. Adjust frequency to 60 Hz at Power Plant panel. ______ Check remote frequency adjustment capability. ______

   i. Check operation of ammeter at Power Plant. ______

   j. Check greaser operation. ______ Set pressure at P_1 to 100 psi. ______

   k. Calibrate tachometer with frequency meter at 60.0 Hz. Tachometer reading. ______ Calculate expected reading for 65.0 Hz and enter in step 24. ______ Calculate expected reading for 66.6 Hz and enter in step 25a.

Date: Test Staff:

Notes:

20. Close Stop metering valve for Automatic Stop valve. _______

21. Hold speed to standard operating RPM or adjust speed to a vibration node if one appeared during startup. Check operation of V_1 two or three times by adjusting sensitivity and adjust for normal plant operation. _______ Log V_1 fault and then no fault. _______ _______ Turn Start switch to reset Stop relay. _______ Check operation of V_2 two or three times by adjusting sensitivity and adjust for normal plant operation. _______ Log V_2 fault and then no fault. _______ Open Stop metering valve. _______

22. With speed adjusted to standard (60.0 Hz generator and 3000 RPM male rotor) cycle exciter to monitor speed change. _______ Note tachometer speed change. _______

23. Turn on voltmeter to monitor OS switch. _______

24. Increase speed to 65.0 Hz and check tachometer for correct reading. Theoretical = 3250. Calculated. _______ Observed. _______

25. If observed tachometer reading does not correlate well with the calculated value, step 23, leave exciter on and set OS switch at 65 Hz using frequency meter as speed reference. Adjust OS switch to open at high end of frequency meter. _______ Reduce speed with governor and note speed at which OS switch closes. _______ Increase speed until OS opens to verify setting. _______ Repeat as necessary.

25a. If observed tachometer reading does correlate well with the calculated value, step 23, turn off exciter and set OS switch using tachometer as speed reference. <u>During this step, continuously monitor RPM and trigger Emergency Stop if RPM exceeds 3450 RPM.</u> Adjust speed to 11% overspeed equal to 3330 RPM male rotor shown on the tachometer as _______ RPM calculated in step 19k.

Date: Test Staff:

Notes:

Set OS switch to just open at this speed. _______ Reduce speed with governor and note speed at which OS switch closes. _______ Increase speed until OS opens to verify setting. _______ Reduce speed to close switch _______ and repeat procedure as necessary.

26. Reduce speed to normal _______ and excite generator _______.

27. Terminate bypass of OS switch by first closing bypass switch _______ anc :hen opening bypass jumper _______.

28. Remove US fault signal jumper _______ and OS fault signal jumper _______ in Van.

29. Using Manual gate valve, reduce RPM to monitor US trip speed. _______ Observe Automatic Stop valve start to close. _______ Log US fault. _______ Press ES at RPM = 1500 if possible and monitor Automatic Stop valve. _______ _______ Log engineering data at intervals until restart. _______

30. Open battery circuit. _______

31. Remove meter from Overspeed signal terminals. _______

32. Remove jumper from OS relay output. _______ Reconnect lead to OS switch output terminal. _______

33. Cl. se Manual gate valve. _______

Date: Test Staff:

Notes:

ACCEPTANCE AND INTERFACE TESTING (Cont'd.)

E. DYNAMIC TEST PROCEDURE: SEMI-NORMAL START, RUN, STOP

1. Walk around Plant inspection. _______Verify that Main Circuit Breaker is open. _______Place Exciter switch in U.S. bypass position. _______ Set inhouse breaker off. _______

2. Manually roll over power train and re-install guard. _______

3. Log engineering data. _______

4. Operate pump #1 to prime lube oil system. _______

5. Close battery switch. _______

6. Reset ES relay. _______

7. Open manual gate valve about 1/3. _______

8. Check nitrogen pressure. _______ Recharge if necessary. _______

9. Hold Start switch on. _______ Observe throttle open. _______

10. While holding Start switch on, operate pump #3 to open Automatic Stop valve part way. _______Watch Tachometer and driving pressure. _______ _______Watch oil pressure to bearings. _______Release Start switch when pressure exceeds LOP point ($\sim$12 psig.). _______Plant will continue to run, throttled by Start/Stop valve.

11. Verify that lube oil reservoir temperature is above 60°F. Otherwise, wait until it is. _______Then continue. Open Automatic Stop valve to bring Plant to standard operating speed, shifting control to the Governor and Throttle. _______Open Automatic Stop valve fully. _______Monitor RPM and adjust Governor as necessary. _______

___________ ___________ ___________ ___________

Date: Test Staff:

Notes:

12. Turn on Exciter. _______Watch Voltmeter and Frequency Meter at Power Plant. _______ _______Look for Ammeter response. _______Adjust frequency to 60 Hz with Governor. _______Adjust voltage to 480 V. _______

13. Check Oil Cooler air flow. _______

14. Cycle the Exciter to check the Governor response. _______Monitor effect on frequency. _______

15. Operate plant three hours. _______Log engineering data. _______Refer to check-list in Appendix. Verify Greaser operation. _______

16. Press Stop button in Van. _______Observe Automatic Stop valve slowly close and bring Plant to a stop. _______

17. Turn off Data Logger. _______Turn off Intercoms. _______

18. Press ES button to open Battery circuit. _______

19. Shut off compressors. _______Bleed off air. _______

20. Close Manual gate valve. _______

__________ __________ __________ __________

Date: Test Staff:

Notes:

APPENDIX L

MILFORD UTAH CLIMATOLOGICAL SUMMARY

Local Climatological Data

Annual Summary With Comparative Data

1974

MILFORD, UTAH

Narrative Climatological Summary

Milford is located in Beaver County in the west-central portion of the State. The City is situated in a flat to gently sloping valley 15 to 20 miles in width. The Mineral Mountains, 10 miles to the east of the station, and the San Francisco Range, 15 miles to the northwest, rise about 5,000 feet above the valley floor.

The station is in the Sevier River Basin, and drainage is toward the north. The Beaver River just to the east extends north-south through the valley, but no significant body of water is reached by it. The river is dry most of the time due to the low annual rainfall in the area, and to the Minersville Reservoir 6 miles east of Minersville, which regulates the flow of water in the stream. Water for the irrigation of agricultural land in the valley is obtained from the diversion of surface water from this reservoir and from numerous deep wells.

The climate is temperate and dry. The average annual precipitation is between 8 and 9 inches, and except for the irrigated land in the valley, vegetation is of the mid-latitude steppe type. Only one month, March, has a normal precipitation amount greater than one inch. Irrigation water is necessary for the economic production of most crops.

Snowfall is rather evenly distributed during the season. The snow is usually light and powdery with below average moisture content. January, the coldest month of the year, has the greatest average monthly total.

Relative humidity is rather low during the summer months. It increases considerably in the change from summer to winter, and winters are cold and uncomfortable.

Summers are characterized by warm days and cool nights. Temperatures of 100° or more occur about once in every two years. July is the hottest month with maximum temperatures on most days above 90°. In four out of five years the temperature can be expected to drop to 10° below zero or lower.

The average growing season is 128 days, rather short for a station near latitude 38° and at an altitude of 5,028 feet. This is due, in part, to the mid-latitude steppe type of climate which normally allows strong radiational cooling during the nighttime hours. The average date of the last freezing temperature, 32° or lower, in the spring is May 21, and the average date of the first freezing temperature in the fall is September 26.

The longest and shortest growing seasons on record are 179 and 80 days, respectively. Considering long-term record, freezing temperatures have occurred as early as August 9, and as late as June 21.

Diurnal heating is a factor in producing strong southerly winds during the spring and summer months. Winter winds may cause considerable drifting snow, with resultant hazards to stock and transportation in the area.

Low pressure storm systems are rare during the summer months. Precipitation during this period occurs as showers or thundershowers and rainfall amounts from these storms are quite variable. As winter approaches, the number of atmospheric disturbances increases, reaching a maximum in the spring of the year.

APPENDIX M

CONDUCTIVITIES OF WATER: NOVEMBER 14, 1979

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APPENDIX M

WATER CONDUCTIVITIES: NOVEMBER 14, 1979

Source	Conductivity Micromhos/cm
Condensate Treatment Tank	360
Processed Condensate from Halliburton Tank	101
Shaft Seal Discharge from Sample Port	2,200
Lube Oil Reservoir	200
Baker Tank (waste)	>20,000
50% Baker Tank, 50% Distilled	8,000
Distilled	7

APPENDIX N

POWER PLANT OPERATOR'S LOG

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		DATE							
		TIME							
	K.W.								
1	P. E.	P.S.I.G.							
2	APROX SEAL	AP'S							
3	MALE H P SEAL	P.							
4	FEMALE H P SEAL	P.							
5	MALE L P SEAL	P.							
6	FEMALE L P SEAL	P.							
7	MAIN OIL PUMP	P.							
8	OIL SUPPLY	P.							
9	OIL SUPPLY	T.							
10	GREASE	P.							
11	GEAR N° 1	T.							
12	GEAR N° 2	T.							
13	GEAR N° 3	T.							
14	GEAR N° 4	T.							
15	SAFETY N-2	P.							
16	SAFETY OIL	P.							
17	SHUTOFF GATE POSITION								
18	SEAL FILTER	Δ P							
19	OIL RESEVOIR LEVEL	IN.							
20	MAIN FILTER N° 1	Δ P							
21	MAIN FILTER N° 2	Δ P							
22	WATER PUMP	P.							
23	WATER FILTER	Δ P							
24	FLUSH WATER FLOW N° 1								
25	FLUSH WATER FLOW N° 2								
26	FLUSH WATER FLOW N° 3								
27	FLUSH WATER FLOW N° 4								
28	CENTRIFUGE WATER FLOW								
29	AIR COMPRESSOR	P.							
30	GREASE VEE BALL								
31	M-11 P W	PSIG							
32	RECIRCULATION FILTER	PSIG							
33	WATER RESEVOIR LEVEL	IN							
34	BEFORE VEE BALL P_1	PSI.G							
35	AFTER VEE BALL P_2	PS.I.G							
36	VEE BALL CONDITION								
37	INLET TEMPERATURE	T.							
38									

APPENDIX O

UNPROCESSED AND AVERAGED DATA: 1978

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RUN NUMBER 2

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
110.7	29.4	350.0	0.0	183.1	30.0	75.6	472.8	104.3	61.2
112.2	25.6	350.0	0.0	183.6	27.4	75.6	474.0	102.0	60.7
112.5	24.3	350.0	0.0	183.6	27.4	78.6	474.6	105.0	60.9
107.6	23.0	350.0	0.0	184.1	27.2	77.4	473.7	105.0	60.5
109.4	22.6	350.0	0.0	184.1	27.3	72.6	473.7	99.0	60.2
107.6	22.4	350.0	0.0	184.6	29.7	75.0	474.3	99.8	60.1
107.3	22.3	350.0	0.0	184.6	30.9	73.2	474.3	99.8	60.2
106.4	23.9	350.0	0.0	184.6	31.0	76.2	474.9	102.0	60.4
106.7	26.2	349.5	0.0	185.1	31.1	73.8	474.6	101.3	60.4
107.6	27.5	349.5	0.0	185.6	31.1	73.2	473.4	100.5	60.3
109.1	29.6	350.0	0.0	186.1	31.0	76.8	472.8	102.0	60.8
109.8	28.9	350.0	0.0	186.1	28.2	79.8	473.4	108.0	61.5
110.7	25.6	350.0	0.0	186.6	26.1	78.6	474.0	103.5	61.0
113.8	24.9	350.0	0.0	187.1	24.5	78.6	473.4	105.8	61.1
112.5	23.9	350.0	0.0	187.1	24.5	73.2	472.5	101.3	60.7
110.1	23.1	350.0	0.0	187.6	24.5	75.6	474.0	102.0	60.3
111.0	22.4	350.0	0.0	188.2	26.4	73.8	472.5	102.8	60.5
110.4	22.2	350.0	0.0	188.2	27.4	74.4	473.7	102.8	60.3
110.4	22.6	349.5	0.0	188.7	29.7	74.4	473.4	101.3	60.3
108.8	24.6	349.5	0.0	188.7	29.7	73.8	472.8	100.5	60.3
107.9	26.4	349.5	0.0	188.7	30.5	72.6	473.7	99.0	60.2
109.1	28.7	349.5	0.0	189.2	30.8	75.0	473.4	102.0	60.7
110.4	29.6	349.5	0.0	189.7	29.6	76.8	473.1	105.0	61.2
112.5	28.3	350.0	0.0	189.7	27.8	79.2	475.2	106.5	61.3
110.4	25.8	350.0	0.0	190.2	25.8	78.0	473.7	104.3	60.8
113.1	24.1	350.0	0.0	190.7	25.5	76.2	472.5	104.3	60.9
108.5	23.2	350.0	0.0	190.7	25.6	75.6	473.4	102.0	60.2
110.7	23.0	350.0	0.0	191.2	27.6	72.6	473.7	99.0	60.1
111.0	22.7	349.5	0.0	191.7	28.4	75.6	473.7	102.9	60.6
106.1	22.6	349.5	0.0	191.7	28.6	76.2	473.7	104.3	60.3

AVERAGE VALUE:

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
109.8	25.0	349.8	0.0	187.4	28.2	75.6	473.6	102.6	60.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
1.69	2.13	0.22	0.00	2.29	1.86	1.68	0.52	1.86	0.34

Number of data points for which the deviation exceeds 2X the average deviation: 1

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RUN NUMBER 3

Fl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
106.7	43.7	342.8	0.0	335.4	39.7	133.8	479.4	165.8	61.0
107.9	43.8	342.8	0.0	335.4	39.9	132.6	479.7	164.3	60.3
109.4	43.0	342.8	0.0	334.8	40.6	134.4	479.1	166.5	61.1
107.3	42.8	343.3	0.0	334.8	40.9	136.2	480.3	165.8	61.3
107.9	43.3	343.3	0.0	334.8	40.9	135.0	479.4	165.0	61.4
108.8	42.1	343.3	0.0	334.8	40.2	133.8	480.0	165.0	61.6
108.5	44.4	343.8	0.0	334.8	38.3	134.4	480.0	165.8	61.2
108.5	42.4	343.8	0.0	334.8	36.6	128.4	478.2	160.5	60.7
110.4	46.2	343.8	0.0	334.8	35.7	129.0	479.7	160.5	60.6
109.4	46.4	343.8	0.0	334.8	35.7	128.4	479.1	159.8	60.4
110.4	45.1	343.8	0.0	334.8	37.0	132.6	479.4	161.3	60.6
110.4	45.6	343.8	0.0	334.8	37.4	132.6	479.4	164.3	60.8
109.8	45.7	343.8	0.0	334.8	37.8	130.2	478.8	159.0	60.6
110.1	45.9	343.8	0.0	334.8	38.3	135.0	480.6	165.8	61.2
109.8	46.3	343.8	0.0	334.8	38.5	133.2	479.7	162.8	61.1
111.3	45.4	343.8	0.0	334.8	38.5	136.2	479.7	167.3	61.3
110.4	45.9	343.8	0.0	334.8	38.5	133.2	478.5	165.8	61.5
110.7	46.0	343.8	0.0	334.8	37.4	136.2	479.4	167.3	61.3
108.8	45.1	343.8	0.0	334.8	36.0	136.2	479.1	166.5	61.4
112.2	51.2	343.3	0.0	334.3	34.7	133.2	480.3	163.5	61.0
111.6	46.0	343.3	0.0	334.3	33.7	127.8	477.9	159.8	60.3
110.4	46.2	343.3	0.0	334.3	38.2	132.6	480.0	160.5	60.2
110.1	47.6	343.3	0	334.3	38.9	135.0	479.7	166.5	60.9
110.4	47.1	343.3	0.0	334.3	38.8	136.2	479.4	169.5	61.5
110.7	46.2	343.3	0.0	334.3	38.9	134.4	480.0	165.8	61.7
109.1	49.1	343.3	0.0	334.3	36.8	135.0	478.8	166.5	61.4
110.1	47.0	343.3	0.0	334.3	35.1	133.2	478.8	164.3	61.0
111.6	44.3	343.3	0.0	334.3	33.6	131.4	480.6	162.0	60.5
111.3	45.0	343.3	0.0	334.3	35.9	131.4	480.0	162.0	60.3
111.0	47.1	343.8	0.0	334.3	37.4	134.4	480.3	164.3	60.9

AVERAGE VALUE:

109.8	45.5	343.5	0.0	334.7	37.7	133.2	479.5	164.1	61.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.05	1.43	0.30	0.00	0.26	1.62	1.88	0.53	2.24	0.36

Number of data points for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS OF POOR QUALITY

RUN NUMBER 4

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
120.2	50.5	352.6	0.0	324.7	42.8	182.4	480.0	219.0	60.7
119.3	51.6	352.0	0.0	325.2	40.7	182.4	480.3	219.0	60.9
120.5	50.7	352.0	0.0	325.2	39.4	177.0	478.2	215.3	60.4
121.4	50.5	352.6	0.0	325.2	39.6	180.0	480.6	217.5	60.3
120.5	51.1	352.6	0.0	324.7	42.0	181.2	479.1	219.8	60.5
120.2	51.7	352.0	0.0	325.2	42.4	181.2	479.7	219.0	60.8
119.9	50.8	352.0	0.0	325.2	42.4	181.2	478.8	220.5	61.0
119.6	51.8	352.0	0.0	325.2	42.6	182.4	478.8	220.5	61.1
119.3	51.8	352.0	0.0	325.2	42.7	181.2	479.1	218.3	61.1
120.5	52.6	352.0	0.0	325.2	41.6	181.8	479.7	219.0	61.2
120.8	51.8	352.0	0.0	325.2	40.0	180.0	479.4	218.3	60.9
119.9	50.1	352.0	0.0	324.7	39.3	180.6	478.8	217.5	60.3
121.7	49.5	352.0	0.0	325.2	41.9	182.4	480.0	219.0	60.5
121.4	49.9	352.0	0.0	325.2	42.5	183.0	480.3	220.5	61.2
120.2	36.0	352.0	0.0	324.7	42.0	182.4	479.7	221.3	61.3
120.2	51.6	352.0	0.0	325.2	40.5	180.6	479.7	216.0	61.0
121.4	50.4	352.0	0.0	324.7	38.9	179.4	478.2	218.3	60.7
121.4	48.9	352.0	0.0	324.7	38.5	181.8	479.4	218.3	60.3
120.8	51.6	352.0	0.0	324.7	41.5	180.0	478.8	218.3	60.6
121.1	50.8	352.0	0.0	325.2	41.9	181.8	479.1	218.3	60.9
120.8	48.8	352.0	0.0	325.2	41.8	180.6	478.5	219.0	61.1
119.6	54.5	352.0	0.0	325.2	41.9	183.0	480.0	220.5	61.1
119.9	52.8	351.5	0.0	324.7	41.8	182.4	479.4	221.3	61.1
119.6	51.2	351.5	0.0	324.7	42.0	183.0	478.5	219.8	61.0
119.9	50.1	352.0	0.0	325.2	41.7	181.2	478.5	220.5	61.1
120.2	50.3	351.5	0.0	325.2	40.1	179.4	478.2	218.3	60.9
119.9	49.7	351.5	0.0	324.7	39.0	179.4	480.0	215.3	60.3
120.8	52.5	352.0	0.0	325.2	42.1	180.0	479.1	218.3	60.5
120.5	46.6	352.0	0.0	325.2	42.4	181.2	478.8	219.8	60.9
120.5	52.1	351.5	0.0	325.2	42.6	182.4	479.4	219.8	61.3

AVERAGE VALUE:

120.4	50.4	352.0	0.0	325.0	41.3	181.2	479.3	218.9	60.8

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.55	1.63	0.16	0.00	0.23	1.13	1.07	0.57	1.17	0.27

Number of data points for which the deviation exceeds 3X the average deviation: 6

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 5

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
105.8	76.7	356.2	0.0	330.8	85.3	293.4	479.4	357.8	60.2
5.1	75.7	356.2	0.0	330.8	86.7	293.4	480.3	356.3	60.1
105.1	76.2	355.6	0.0	330.8	87.6	294.0	479.4	357.8	60.3
104.8	76.2	355.6	0.0	330.8	87.5	295.2	479.1	360.8	60.4
105.1	76.1	355.6	0.0	330.8	87.7	294.6	478.8	359.3	60.4
104.2	77.8	355.6	0.0	330.8	87.5	293.4	47 .7	357.8	60.3
104.5	77.1	355.1	0.0	330.8	87.6	293.4	480.6	356.3	60.3
104.2	77.6	355.1	0.0	330.8	87.5	292.2	479.1	357.0	60.2
104.5	78.3	355.1	0.0	330.8	87.7	294.6	480.6	356.3	60.2
104.5	78.5	355.1	0.0	330.8	87.6	294.0	479.1	359.3	60..
104.8	78.1	355.1	0.0	330.8	87.8	294.6	479.1	357.8	60.4
104.8	78.6	354.6	0.0	330.3	87.5	293.4	479.4	357.8	60.4
104.2	78.5	354.6	0.0	330.3	87.6	294.6	479.4	357.0	60.3
104.2	78.6	354.6	0.0	330.3	87.7	293.4	479.1	356.3	60.2
104.2	78.5	354.1	0.0	330.3	87.8	293.4	479.4	357.0	60.3
104.8	78.6	354.1	0.0	330.3	87.6	295.2	480.3	357.0	60.3
104.2	78.3	354.1	0.0	330.3	87.8	292.8	479.1	356.3	60.2
103.3	78.1	354.1	0.0	330.3	87.6	291.0	479.7	354.0	60.1
103.6	77.8	354.1	0.0	330.3	88.5	291.6	480.0	355.5	60.1
103.9	78.5	354.1	0.0	330.3	88.9	294.6	479.4	359.3	60.3
103.3	78.3	354.1	0.0	330.3	89.1	293.4	480.3	356.3	60.3
103.6	78.0	354.1	0.0	330.3	89.3	293.4	479.1	357.8	60.3
103.6	78.4	354.1	0.0	330.3	89.4	294.0	479.4	357.0	60.3
103.3	78.8	354.1	0.0	330.3	89.8	292.8	478.8	357.0	60.2
102.7	78.8	354.1	0.0	330.3	90.0	292.8	479.4	356.3	60.2
103.0	78.7	354.1	0.0	330.3	90.6	293.4	479.1	356.3	60.2
103.9	78.8	354.1	0.0	330.3	90.8	294.0	479.7	357.0	60.3
102.7	78.5	354.1	0.0	330.3	90.8	294.6	480.6	357.0	60.4
102.7	78.6	354.1	0.0	330.3	90.8	294.6	480.6	357.0	60.4
102.4	79.0	354.1	0.0	330.3	90.9	294.0	479.1	357.0	60.3

AVERAGE VALUE:

104.1	78.0	354.7	0.0	330.4	88.4	293.7	479.5	357.2	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.71	0.72	0.61	0.00	0.24	1.20	0.76	0.48	0.90	0.07

Number of data points for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 6

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
129.4	87.6	367.4	0.0	326.7	68.0	340.8	475.5	412.5	60.3
128.5	82.7	366.9	0.0	326.7	68.5	340.8	475.2	412.5	60.3
128.5	82.5	366.9	0.0	326.7	68.3	342.0	476.7	412.5	60.4
127.9	82.3	366.9	0.0	326.7	68.5	340.8	4[illegible]5.2	413.3	60.3
127.[illegible]	86.4	36[illegible]	0.0	326.7	68.4	339.6	475.5	413.3	60.3
128.5	57.9	366.9	0.0	326.7	68.5	340.2	475.2	411.8	60.3
128.5	84.8	366.9	0.0	326.7	68.5	340.8	476.7	411.8	60.3
128.5	87.0	366.9	0.0	326.7	68.5	340.8	475.5	411.8	60.3
128.2	96.0	366.9	0.0	326.7	68.5	339.6	475.8	413.3	60.3
129.1	84.5	366.9	0.0	326.2	68.8	340.8	476.1	413.3	60.4
128.2	82.3	366.9	0.0	326.7	68.7	342.6	476.7	414.0	60.4
128.2	81.8	367.4	0.0	326.7	68.5	340.8	476.4	412.5	60.4
128.2	82.5	367.4	0.0	326.2	68.7	342.6	475.2	414.8	60.4
128.8	82.0	367.4	0.0	326.7	68.5	342.0	477.0	413.3	60.5
128.8	94.7	367.4	0.0	326.2	68.6	341.4	475.5	414.0	60.4
129.1	45.5	367.4	0.0	326.2	66.9	339.6	475.8	411.8	60.3
129.7	89.6	367.4	0.0	326.2	66.9	338.4	476.7	411.0	60.1
130.0	89.6	367.4	0.0	326.2	67.5	340.8	476.7	411.0	60.2
128.8	42.0	367.4	0.0	326.7	68.0	340.2	475.5	412.5	60.3
129.4	87.2	367.4	0.0	326.2	67.9	342.0	475.5	414.0	60.4

AVERAGE VALUE:

128.7	80.5	367.2	0.0	326.5	68.2	340.8	475.9	412.7	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.48	9.59	0.26	0.00	0.23	0.41	0.76	0.56	0.85	0.06

umber of data points for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 8

P1	Mf	Tf	Mv	Tv	Ts	KW	volts	amps	freq
125.1	26.6	359.2	14.8	383.7	55.1	269.4	480.0	324.0	59.8
123.0	27.3	359.2	13.1	383.2	55.0	270.6	480.6	324.0	59.7
126.3	27.6	359.2	15.5	383.2	56.0	270.6	480.0	325.5	59.6
124.5	27.2	359.2	16.9	383.2	56.5	270.6	480.9	324.8	60.0
124.5	27.6	359.2	14.6	383.2	56.6	270.6	480.0	324.8	60.2
123.3	28.5	359.2	8.5	383.2	56.6	269.4	479.4	324.0	59.9
123.9	27.6	359.2	14.7	383.2	56.6	270.0	480.0	324.0	59.8
123.3	32.5	359.2	15.1	383.2	56.5	270.6	480.0	325.5	59.9
123.6	25.7	359.2	16.7	383.2	57.0	270.6	479.1	324.8	59.9
124.2	28.9	359.2	19.0	383.7	56.7	270.6	479.4	325.5	60.3
124.5	29.6	359.2	13.2	383.7	56.8	270.0	479.4	324.8	60.2
125.1	27.6	359.2	13.4	383.7	56.2	269.4	480.0	324.0	60.3
126.3	28.6	359.2	15.4	383.7	55.9	270.6	480.0	324.8	60.3
125.1	29.3	359.2	16.1	383.7	55.1	270.0	480.6	324.0	60.3
126.3	28.1	359.2	11.6	383.7	54.6	269.4	480.9	323.3	60.2
126.7	30.3	358.7	14.0	383.7	54.5	268.8	479.4	324.0	59.8
126.7	27.4	358.7	14.0	383.2	54.4	270.0	480.6	323.3	59.8
127.3	23.8	359.2	14.2	383.7	54.5	270.6	479.4	325.5	59.6
128.2	27.1	358.7	16.8	383.2	55.6	271.8	480.6	325.5	59.8
125.7	24.3	359.2	15.8	383.2	55.9	270.6	480.0	325.5	59.8
124.8	27.1	359.2	15.5	383.2	56.3	270.6	479.7	324.0	59.9

AVERAGE VALUE:

125.2	27.7	359.2	14.7	383.5	55.8	270.2	480.0	324.5	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.17	1.31	0.13	1.50	0.25	0.74	0.54	0.40	0.65	0.20

Line# 6 Col# 4
Line# 8 Col# 2
Line# 16 Col# 3
Line# 17 Col# 3
Line# 18 Col# 2
Line# 19 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 6

ORIGINAL PAGE IS OF POOR QUALITY

RUN NUMBER 9

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
111.2	74.8	350.3	0.0	371.3	87.6	340.2	480.6	413.3	60.7
110.0	73.9	350.4	0.0	371.3	87.1	340.2	480.3	414.8	60.7
111.2	72.1	350.3	0.0	371.3	87.1	341.4	481.5	413.3	60.6
112.1	73.8	350.4	0.0	371.3	87.7	342.6	480.3	414.8	60.7
110.0	70.3	350.2	0.0	371.3	87.3	340.2	480.9	413.3	60.7
111.8	83.6	350.2	0.0	371.3	87.4	342.0	480.9	412.5	60.6
110.0	76.4	350.2	0.0	371.4	87.4	339.0	480.3	413.3	60.6
111.5	75.6	350.2	0.0	371.4	87.4	340.2	481.2	414.0	60.6
110.9	71.4	350.1	0.0	371.5	87.7	341.4	480.6	414.0	60.6
111.2	75.6	350.0	0.0	371.5	87.5	341.4	480.3	414.0	60.6
112.1	77.3	350.1	0.0	371.6	87.2	343.2	480.3	417.9	60.8
110.0	83.6	350.1	0.0	371.6	86.8	340.2	480.0	414.8	60.7
112.4	75.8	350.2	0.0	371.6	87.0	339.6	480.6	414.8	60.7
111.8	75.7	350.1	0.0	371.5	86.4	342.0	480.3	414.8	60.7
111.2	75.4	350.2	0.0	371.6	86.3	340.2	480.3	414.8	60.7
110.6	72.4	350.1	0.0	371.6	86.3	341.4	481.2	413.3	60.7
112.7	74.0	350.1	0.0	371.6	86.3	343.2	481.5	414.0	60.7
112.7	67.8	350.1	0.0	371.6	86.1	340.2	480.3	414.0	60.7
112.1	72.8	350.0	0.0	371.6	85.8	340.2	480.6	412.5	60.6
113.4	76.2	350.1	0.0	371.6	86.0	343.2	481.5	414.0	60.6
111.8	77.7	350.0	0.0	371.6	86.1	342.0	480.6	414.8	60.7
111.8	71.6	350.0	0.0	371.6	86.1	340.8	480.3	414.0	60.7
111.2	77.8	350.0	0.0	371.6	85.7	339.6	480.3	412.5	60.6
112.7	76.8	350.0	0.0	371.6	85.4	340.8	481.8	413.3	60.7
112.7	75.3	349.9	0.0	371.6	86.0	340.8	480.6	413.3	60.6
111.2	74.9	349.8	0.0	371.6	85.4	339.0	480.3	412.5	60.6
112.1	75.6	349.8	0.0	371.6	85.9	340.8	480.9	412.5	60.5
113.7	76.4	349.9	0.0	371.6	85.6	342.0	480.3	414.8	60.6
112.1	73.9	349.9	0.0	371.6	85.7	341.4	480.9	414.8	60.7
112.4	74.0	349.8	0.0	371.6	86.2	343.2	480.9	415.5	60.6

AVERAGE VALUE:

111.7	75.1	350.1	0.0	371.5	86.5	341.1	480.7	414.0	60.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.80	2.24	0.13	0.00	0.11	0.65	1.02	0.38	0.93	0.04

Line# 6 Col# 2
Line# 11 Col# 9
Line# 12 Col# 2
Line# 18 Col# 2
Line# 27 Col# 10

Number of data sets for which the deviation exceeds 3X the average deviation: 5

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 10

P1	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
111.8	71.2	349.8	0.0	371.7	85.8	340.2	481.5	414.0	60.8
112.7	74.2	349.9	0.0	371.7	85.5	339.6	480.6	413.3	60.7
113.1	71.4	349.8	0.0	371.7	85.2	340.2	481.2	414.0	60.6
112.7	60.7	349.8	0.0	371.7	85.5	340.8	480.0	415.5	60.7
111.5	76.1	349.8	0.0	371.7	85.6	340.2	480.9	413.3	60.7
111.8	76.0	349.7	0.0	371.7	85.3	339.6	480.0	412.5	60.6
112.7	74.3	349.8	0.0	371.7	85.5	340.2	480.0	414.0	60.6
112.4	70.1	349.8	0.0	371.6	85.4	341.4	480.9	414.8	60.7
111.8	75.9	349.9	0.0	371.6	85.5	340.2	481.5	414.0	60.7
112.1	76.3	349.9	0.0	371.7	85.6	342.0	481.2	413.3	60.7
112.7	74.3	349.9	0.0	371.6	85.5	342.0	480.0	414.0	60.7
113.1	74.4	349.8	0.0	371.7	85.7	339.6	480.0	413.3	60.7
113.7	71.5	349.8	0.0	371.7	85.4	342.6	480.0	415.5	60.7
113.7	76.9	349.8	0.0	371.7	85.4	342.6	480.3	414.0	60.7
113.1	74.7	349.7	0.0	371.7	85.4	340.8	481.2	414.0	60.7
113.4	75.2	349.8	0.0	371.6	85.4	342.6	480.6	414.0	60.7
113.4	70.1	349.8	0.0	371.7	85.4	341.4	480.3	412.5	60.9
112.1	76.2	349.8	0.0	371.6	85.3	342.6	480.0	412.5	60.7
113.4	74.3	349.8	0.0	371.6	85.2	342.6	480.0	415.5	60.7
114.0	75.6	349.8	0.0	371.6	85.1	343.2	480.0	416.3	60.7

AVERAGE VALUE:

112.9	73.5	349.8	0.0	371.7	85.5	341.2	480.5	414.0	60.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.57	2.59	0.03	0.00	0.03	0.13	1.08	0.50	0.75	0.03

Line# 4 Col# 2
Line# 6 Col# 3
Line# 15 Col# 3
Line# 20 Col# 6

Number of data sets for which the deviation exceeds 3X the average deviation: 4

RUN NUMBER 11

Pl	Mf	Tf	Mv	Tv	TS	kW	volts	amps	freq
104.1	60.6	356.1	0.0	376.0	97.7	337.2	480.3	409.5	60.5
103.5	59.2	356.1	0.0	375.8	97.6	337.2	480.3	408.8	60.4
103.2	57.8	356.1	0.0	375.5	97.7	336.6	480.0	408.0	60.4
103.5	58.0	356.1	0.0	375.3	97.6	337.2	480.6	409.5	60.3
102.3	55.7	356.1	0.0	374.9	97.9	335.4	481.8	405.8	60.2
100.7	54.6	356.1	0.0	374.4	99.4	335.4	481.8	405.8	60.0
102.0	61.2	356.1	0.0	373.8	99.4	335.4	481.2	405.9	60.0
101.1	62.3	356.2	0.0	373.3	99.7	336.0	480.0	407.3	60.0
103.5	62.7	356.2	0.0	372.9	99.5	337.8	480.3	411.0	60.2
105.1	65.3	356.1	0.0	372.4	99.6	342.0	479.4	415.5	60.7
103.5	61.8	356.2	0.0	372.1	99.6	342.0	481.5	414.0	61.0
104.[illegible]	67.0	356.2	0.0	372.0	99.6	343.8	480.9	416.3	61.2
106.3	66.8	356.2	0.0	372.0	95.1	342.6	480.6	415.5	61.2
107.2	70.0	356.3	0.0	372.1	93.3	342.0	480.3	414.9	61.1
107.8	69.5	356.3	0.0	372.3	91.6	340.8	480.3	414.8	61.1
109.7	64.0	356.3	0.0	372.4	90.1	342.0	480.3	415.5	61.1
110.9	61.6	356.3	0.0	372.3	88.5	342.6	480.6	415.5	61.0
110.9	61.5	356.2	0.0	372.0	87.5	340.8	481.2	413.3	61.0
110.6	59.9	356.2	0.0	371.6	86.2	339.0	480.6	413.3	60.8
111.8	60.7	356.3	0.0	371.2	85.3	339.0	481.5	410.3	60.6

AVERAGE VALUE:

105.6	62.0	356.2	0.0	373.2	95.1	339.2	480.7	411.5	60.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

3.02	3.16	0.06	0.00	1.32	4.35	2.54	0.52	3.34	0.37

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 12

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
107.5	61.0	355.9	0.0	355.0	92.4	339.0	480.9	410.3	60.5
107.8	60.3	355.9	0.0	354.7	92.4	339.6	479.4	412.5	60.5
107.8	61.5	355.9	0.0	354.6	92.3	339.0	481.2	411.0	60.6
107.2	59.1	355.9	0.0	354.6	92.3	338.4	479.7	412.5	60.5
106.6	61.8	355.9	0.0	354.6	92.4	339.0	480.6	411.0	60.6
107.2	60.3	355.9	0.0	354.5	92.2	337.8	479.7	411.0	60.5
107.5	60.8	355.8	0.0	354.5	92.4	340.2	480.0	412.5	60.5
107.8	61.7	355.9	0.0	354.4	92.2	339.0	480.9	412.5	60.5
107.5	59.9	355.9	0.0	354.4	92.4	338.4	479.7	412.5	60.5
107.5	61.0	355.9	0.0	354.4	92.3	339.0	481.2	411.0	60.6
107.2	61.3	355.9	0.0	354.4	92.4	339.6	479.7	412.5	60.6
107.5	61.6	355.9	0.0	354.4	92.1	339.0	480.6	411.8	60.6
107.2	60.6	355.9	0.0	354.4	92.2	339.6	480.6	411.8	60.7
107.5	62.1	355.9	0.0	354.4	92.0	339.0	480.0	412.5	60.6
107.5	61.6	355.9	0.0	354.3	91.9	338.4	481.2	410.3	60.6
106.6	59.9	355.9	0.0	354.2	91.9	339.6	479.7	411.9	60.5
108.1	62.5	355.9	0.0	354.2	91.9	339.6	481.2	411.8	60.6
108.1	60.6	355.9	0.0	354.2	91.8	339.0	479.7	412.5	60.6
108.1	61.6	355.9	0.0	354.2	91.8	339.0	481.2	411.8	60.6
108.1	61.2	355.8	0.0	354.2	91.8	339.6	479.7	412.5	60.5
107.8	60.0	355.9	0.0	354.2	91.8	339.6	481.2	411.8	60.6
108.1	60.9	355.9	0.0	354.1	91.5	338.4	480.0	411.0	60.5
108.1	61.7	355.9	0.0	354.1	91.9	339.6	479.4	411.0	60.5
108.1	61.2	355.9	0.0	354.0	91.7	338.4	481.2	411.0	60.6
107.8	62.0	355.9	0.0	354.0	91.8	339.0	480.0	413.2	60.6
108.1	61.5	355.8	0.0	353.9	91.7	339.6	481.2	411.8	60.6
106.9	60.7	355.8	0.0	353.9	91.8	339.6	479.7	412.5	60.5
107.2	61.2	355.8	0.0	353.9	91.9	339.6	480.3	410.3	60.5
107.5	61.3	355.9	0.0	353.8	91.6	338.4	480.3	410.3	60.5
108.1	61.9	355.9	0.0	353.7	91.9	339.6	479.4	411.8	60.6

AVERAGE VALUE:

107.6	61.1	355.9	0.0	354.3	92.0	339.1	480.3	411.7	60.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.38	0.61	0.02	0.00	0.23	0.23	0.46	0.50	0.70	0.03

Line# 1 Col# 5
Line# 4 Col# 2
Line# 7 Col# 3
Line# 13 Col# 10
Line# 20 Col# 3
Line# 26 Col# 3
Line# 27 Col# 3
Line# 28 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 8

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 13

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
147.5	61.9	356.0	0.0	345.8	41.0	337.8	479.4	410.3	60.4
147.5	62.5	356.0	0.0	345.6	40.8	336.6	480.0	408.8	60.2
147.5	62.9	356.0	0.0	345.6	40.8	337.8	480.0	410.3	60.3
147.8	61.8	356.0	0.0	345.6	40.7	338.4	481.2	410.3	60.3
147.5	62.1	356.0	0.0	345.6	40.9	337.8	480.0	411.0	60.4
147.5	61.2	356.0	0.0	345.6	40.9	338.4	480.3	410.3	60.4
147.5	62.8	356.0	0.0	345.6	40.9	338.4	480.3	411.0	60.4
147.5	62.2	356.1	0.0	345.6	40.9	337.2	480.0	410.3	60.4
147.5	61.8	356.1	0.0	345.4	40.8	337.2	480.0	409.5	60.3
147.8	61.7	356.1	0.0	345.5	40.8	336.6	480.0	409.5	60.2
147.8	62.8	356.1	0.0	345.4	40.6	337.2	480.9	409.5	60.3
147.8	62.1	356.1	0.0	345.4	40.8	337.8	479.7	408.8	60.3
148.1	61.6	356.1	0.0	345.3	40.8	337.8	480.0	411.8	60.4
147.8	62.1	356.1	0.0	345.3	40.7	337.2	480.0	410.3	60.4
148.1	63.2	356.1	0.0	345.1	40.5	337.2	480.0	409.5	60.3
148.1	61.8	356.1	0.0	345.1	40.4	336.6	481.2	408.0	60.2
147.8	59.6	356.1	0.0	345.1	40.5	336.6	479.7	408.0	60.2
148.1	60.3	356.1	0.0	345.1	40.5	338.4	480.9	409.5	60.3
147.8	61.7	356.1	0.0	345.1	40.6	337.8	479.7	410.3	60.3
148.1	62.7	356.1	0.0	345.1	40.4	337.2	480.0	410.3	60.3

AVERAGE VALUE:

147.8	61.9	356.1	0.0	345.4	40.7	337.5	480.2	409.8	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.21	0.61	0.05	0.00	0.20	0.16	0.54	0.38	0.75	0.05

Line# 17 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 14

Pl	Mf	Tf	Mv	Tv	T*	kW	volts	amps	freq
138.9	67.8	352.2	0.0	339.8	50.1	337.8	480.9	410.3	60.1
138.6	67.8	352.2	0.0	339.9	49.9	337.2	481.2	408.8	60.1
138.9	66.0	352.3	0.0	339.8	50.1	337.8	481.2	408.8	60.0
138.6	67.2	352.3	0.0	339.7	50.0	337.2	481.2	408.8	60.1
138.9	67.2	352.3	0.0	339.7	50.0	337.2	481.2	408.8	60.1
138.6	67.4	352.3	0.0	339.7	50.0	336.0	480.9	408.8	60.1
138.6	66.9	352.4	0.0	339.6	50.1	337.2	480.3	409.5	60.2
138.9	67.3	352.3	0.0	339.6	50.2	337.2	480.0	409.5	60.1
138.9	66.6	352.3	0.0	339.5	50.2	336.6	480.0	409.5	60.1
138.9	66.4	352.4	0.0	339.5	50.2	336.0	480.0	409.5	60.0
138.6	66.9	352.4	0.0	339.5	50.4	337.2	480.0	410.3	60.0
138.6	67.4	352.3	0.0	339.5	50.5	337.2	479.7	410.3	60.1
138.9	70.9	352.3	0.0	339.5	50.4	337.2	480.0	409.5	60.1
138.3	67.2	352.3	0.0	339.5	53.2	340.8	480.0	414.8	60.5
138.0	67.8	352.4	0.0	339.5	53.2	342.6	480.9	415.5	60.8
138.0	67.5	352.4	0.0	339.5	52.6	342.0	480.0	415.5	60.8
137.7	69.7	352.3	0.0	339.5	52.0	340.2	481.2	412.5	60.6
137.7	67.6	352.3	0.0	339.4	51.7	338.4	480.0	411.9	60.4
137.7	67.0	352.3	0.0	339.4	51.6	339.0	480.3	411.8	60.3
137.7	66.5	352.3	0.0	339.3	51.8	339.0	481.5	411.0	60.3

AVERAGE VALUE:

138.4	67.5	352.3	0.0	339.6	50.9	338.2	480.5	410.7	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.42	0.70	0.03	0.00	0.11	0.98	1.47	0.55	1.76	0.21

Line# 13 Col# 2
Line# 15 Col# 7
Line# 17 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 15

Pl	Mf	Tf	Mv	Tv	Ta	kV	volts	amps	freq
126.0	92.7	344.9	0.0	241.8	63.5	345.6	477.3	421.5	60.8
126.0	92.7	344.9	0.0	241.7	63.6	346.8	477.0	421.5	60.9
126.0	91.9	344.9	0.0	241.6	63.5	346.2	477.9	420.8	60.9
126.0	92.3	344.8	0.0	241.5	63.3	346.2	477.0	422.3	60.9
126.0	92.1	344.8	0.0	241.5	63.6	346.2	477.3	420.8	60.8
126.0	91.9	344.8	0.0	241.5	63.3	346.2	477.9	420.8	60.9
126.3	92.5	344.8	0.0	241.5	63.4	346.2	476.7	422.3	60.9
126.3	92.8	344.8	0.0	241.5	63.5	346.8	478.2	420.8	60.9
126.0	92.2	344.8	0.0	241.4	63.3	345.6	476.7	421.5	60.8
126.0	92.2	344.7	0.0	241.3	63.5	346.2	476.7	421.5	60.8
126.0	92.5	344.7	0.0	241.3	63.3	345.6	477.9	420.8	60.8
126.0	91.6	344.8	0.0	241.2	63.3	346.2	476.7	421.5	60.9
126.0	92.8	344.8	0.0	241.1	63.5	346.2	477.0	420.8	60.9
126.0	91.7	344.9	0.0	241.0	63.3	346.2	477.9	420.8	60.9
126.0	92.8	344.8	0.0	241.0	63.3	346.2	477.9	421.5	60.9
126.0	93.8	344.8	0.0	241.0	63.5	346.8	476.7	421.5	60.9
126.0	92.5	344.8	0.0	240.9	63.3	346.8	477.3	421.5	60.9
126.3	91.6	344.8	0.0	240.8	63.5	346.2	476.7	420.8	60.9
126.3	92.5	344.8	0.0	240.8	63.4	346.2	478.2	420.8	60.9
126.0	91.7	344.8	0.0	240.8	63.3	346.8	477.0	422.3	60.9

AVERAGE VALUE:

126.0	92.3	344.8	0.0	241.3	63.4	346.3	477.3	421.3	60.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.10	0.41	0.03	0.00	0.27	0.10	0.27	0.48	0.47	0.02

Line# 1 Col# 3
Line# 16 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 16

P1	Mf	Tf	Mv	Tv	Ta	kV	volts	amps	freq
115.5	117.0	339.5	0.0	223.9	81.2	351.0	477.6	426.0	60.7
115.5	115.8	339.5	0.0	223.9	81.0	351.0	477.0	426.8	60.7
115.2	115.7	339.5	0.0	223.9	80.9	351.0	477.6	426.8	60.7
115.2	115.6	339.5	0.0	223.9	81.0	351.0	479.2	426.3	60.7
115.2	115.2	339.5	0.0	223.9	81.2	351.6	477.0	426.8	60.7
115.2	115.7	339.5	0.0	223.9	81.1	351.6	476.7	427.5	60.6
115.5	115.7	339.5	0.0	223.9	81.0	350.4	476.7	426.8	60.7
115.8	118.0	339.5	0.0	223.9	80.9	350.4	476.7	426.8	60.7
115.2	116.5	339.5	0.0	223.9	80.9	350.4	477.3	426.8	60.7
115.5	116.2	339.5	0.0	223.9	81.0	351.0	478.2	426.0	60.7
115.5	116.5	339.5	0.0	223.9	81.2	351.0	477.6	426.0	60.7
115.5	116.6	339.5	0.0	223.9	81.2	350.4	476.7	426.8	60.7
115.2	116.1	339.5	0.0	223.9	81.1	350.4	476.7	427.5	60.6
115.2	115.3	339.5	0.0	223.9	81.0	350.4	477.3	426.0	60.6
115.2	116.6	339.4	0.0	223.9	81.1	351.0	477.6	426.0	60.6
115.2	116.4	339.5	0.0	223.9	81.1	350.4	476.7	427.5	60.6
115.5	115.4	339.5	0.0	223.9	81.0	349.8	477.0	426.9	60.6
115.2	117.2	339.4	0.0	223.9	81.2	349.8	477.3	426.8	60.6
115.2	115.5	339.4	0.0	223.9	81.2	349.8	476.7	426.8	60.6
115.2	115.3	339.4	0.0	223.9	81.1	349.8	477.3	426.0	60.6

AVERAGE VALUE:

115.3	116.1	339.5	0.0	223.9	81.1	350.6	477.2	426.5	60.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.17	0.59	0.02	0.00	0.00	0.09	0.47	0.41	0.38	0.03

Line# 8 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 17

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
113.4	158.4	335.5	0.0	223.9	85.3	357.6	473.7	436.5	60.7
113.4	157.6	335.4	0.0	223.9	85.2	357.0	473.1	436.5	60.7
113.1	158.6	335.4	0.0	223.9	85.4	357.0	472.2	437.3	60.6
113.4	157.5	335.4	0.0	223.9	85.2	357.0	471.9	437.3	60.7
113.4	157.1	335.5	0.0	223.9	85.2	357.0	472.5	436.5	60.7
113.4	158.5	335.5	0.0	223.9	85.2	358.2	473.4	436.5	60.7
113.7	158.0	335.6	0.0	223.9	85.3	358.2	473.4	437.3	60.7
113.7	158.5	335.6	0.0	223.9	85.3	358.9	473.4	437.3	60.8
113.4	156.5	335.7	0.0	223.9	85.2	358.8	473.1	438.0	60.8
113.4	157.5	335.7	0.0	223.9	85.2	359.4	472.2	438.8	60.8
113.7	158.7	335.7	0.0	223.9	85.1	358.2	472.8	438.0	60.8
113.4	158.6	335.7	0.0	223.9	85.3	358.8	472.2	436.5	60.8
113.7	157.6	335.7	0.0	223.9	85.1	358.2	472.5	438.0	60.8
113.7	158.0	335.7	0.0	223.9	84.6	358.2	471.9	437.3	60.7
113.4	157.2	335.7	0.0	223.9	84.2	357.0	472.2	437.3	60.7
113.7	155.8	335.7	0.0	223.9	84.4	357.6	471.9	437.3	60.7
113.7	157.0	335.7	0.0	223.9	84.2	357.0	472.2	436.5	60.6
113.7	157.5	335.7	0.0	223.9	84.2	357.6	473.1	436.5	60.7
113.7	156.2	335.7	0.0	223.9	84.3	357.6	473.7	436.5	60.7
113.7	156.7	335.7	0.0	223.9	84.4	357.6	472.5	435.9	60.7

AVERAGE VALUE:

113.5	157.6	335.6	0.0	223.9	84.9	357.8	472.7	437.1	60.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.17	0.67	0.09	0.00	0.00	0.43	0.52	0.54	0.58	0.05

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS OF POOR QUALITY

RUN NUMBER 18

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
156.7	76.2	351.7	27.7	373.9	45.3	327.0	479.1	392.3	60.2
154.3	77.6	351.7	28.0	374.0	45.5	327.6	478.5	393.0	60.3
155.5	76.7	351.9	27.7	373.9	45.4	328.2	478.8	393.0	60.3
155.8	76.3	351.7	28.0	374.0	45.4	327.0	478.5	393.8	60.4
154.9	77.1	351.9	27.7	373.9	45.4	327.0	478.5	393.0	60.4
154.3	77.5	351.8	27.6	374.0	45.5	327.0	478.2	393.0	60.4
153.4	75.7	351.8	28.0	373.9	45.5	327.6	477.3	393.8	60.4
156.7	79.1	351.8	28.0	374.0	45.6	327.6	477.9	393.0	60.5
154.6	78.9	351.8	28.7	374.0	45.4	327.0	479.1	392.3	60.5
156.4	[illegible].2	351.9	28.0	374.1	45.4	327.0	477.6	393.8	60.5
155.8	77.9	351.9	28.8	374.1	45.6	326.4	477.3	392.3	60.4
154.3	77.0	351.9	28.2	374.1	45.5	327.6	477.3	392.3	60.4
155.8	78.8	351.9	28.3	374.0	45.5	327.6	477.6	392.3	60.3
154.0	75.2	351.9	27.7	374.1	45.5	327.0	478.5	393.0	60.3
155.5	77.9	352.0	27.7	374.1	45.4	327.0	477.9	393.0	60.3
155.5	76.3	352.0	27.8	374.1	45.3	327.6	479.4	392.3	60.3
155.5	78.1	352.0	27.8	374.1	45.5	327.0	477.9	392.3	60.3
155.8	77.2	352.0	28.0	374.1	45.6	325.8	477.6	393.0	60.3
155.8	74.4	352.0	26.9	374.1	45.4	325.4	477.6	392.3	60.3
156.1	75.9	352.0	27.8	374.1	45.3	325.8	478.2	391.5	60.3

AVERAGE VALUE:

155.3	77.0	351.9	27.9	374.0	45.4	327.1	478.1	392.7	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.77	1.00	0.07	0.28	0.05	0.08	0.44	0.54	0.51	0.06

Line# 11 Col# 4
Line# 19 Col# 4

Number of data sets for which the deviation exceeds 3X the average deviation: 2

RUN NUMBER 19

Pl	Mf	Tf	Mv	Tv	T%	kV	volts	amps	freq
96.4	46.3	343.3	51.0	370.0	97.0	330.0	477.0	396.0	60.2
95.5	47.0	343.3	50.7	370.0	97.1	329.4	477.0	395.3	50.2
96.1	46.2	343.3	50.4	370.0	96.9	329.4	477.3	395.3	60.2
96.1	46.7	343.4	50.7	370.0	97.1	330.0	477.0	395.3	[illegible].1
95.5	46.9	343.4	50.8	369.9	97.0	330.0	478.2	395.3	60.2
95.8	46.7	343.4	50.6	370.0	97.2	329.4	477.0	396.0	60.2
96.4	46.5	343.4	50.3	370.0	97.1	330.0	478.2	396.0	60.2
95.2	46.8	343.4	51.3	370.0	97.3	329.4	476.7	396.0	60.2
96.7	47.2	343.4	50.7	369.9	97.2	329.4	477.0	396.0	60.2
95.5	46.6	343.4	50.6	370.0	97.0	330.0	478.2	395.3	60.2
95.8	46.6	343.4	51.0	370.0	97.0	330.0	478.2	395.3	60.2
95.5	46.9	343.4	50.9	369.9	97.1	329.4	476.7	396.0	60.1
96.1	46.7	343.4	50.5	370.0	97.3	330.0	477.0	396.0	60.2
96.1	46.9	343.4	50.7	370.0	97.1	329.4	477.9	395.3	60.1
95.8	46.6	343.4	50.4	369.9	97.3	328.2	477.0	395.3	60.1
95.8	46.5	343.4	50.8	370.0	97.4	330.0	476.4	396.0	60.2
95.2	47.0	343.4	50.7	370.0	97.3	330.0	478.2	395.3	60.2
95.2	46.7	343.5	50.5	370.0	97.4	329.4	476.7	396.0	60.1
95.8	46.3	343.5	50.6	369.9	97.5	329.4	476.4	396.0	60.1
96.1	46.8	343.5	51.2	370.0	97.4	330.0	478.5	396.0	60.2

AVERAGE VALUE:

95.9	46.7	343.4	50.7	369.9	97.2	329.6	477.3	395.7	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.34	0.19	0.02	0.20	0.03	0.14	0.36	0.61	0.37	0.03

Line# 1 Col# 3
Line# 2 Col# 3
Line# 3 Col# 3
Line# 9 Col# 4
Line# 15 Col# 7
Line# 18 Col# 3
Line# 19 Col# 3
Line# 20 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 8

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 20

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
94.9	47.2	343.4	51.2	370.0	98.3	328.8	478.5	394.5	60.2
95.8	46.8	343.4	50.9	370.0	98.5	330.0	477.0	396.9	60.2

AVERAGE VALUE:

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
95.4	47.0	343.4	51.0	370.0	98.4	329.4	477.8	395.6	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
0.46	0.22	0.00	0.19	0.00	0.10	0.60	0.75	1.13	0.01

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 21

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
96.1	46.8	343.5	50.5	370.0	98.5	328.8	476.4	397.5	60.2
94.9	46.1	343.5	50.7	370.0	98.3	329.4	478.2	394.5	60.1
95.8	47.0	343.5	51.2	369.9	98.4	329.4	477.6	395.3	60.1
94.9	47.[illegible]	343.5	50.8	369.9	98.5	328.8	477.0	396.0	60.1
95.5	46.5	343.5	51.0	370.0	98.5	328.8	476.7	396.0	60.1
95.2	46.1	343.5	50.9	370.0	98.4	329.4	477.9	394.5	60.1
95.5	46.6	343.5	51.0	369.9	98.3	328.8	477.9	395.3	60.1
95.2	46.9	343.5	50.7	369.9	98.4	328.8	477.0	395.3	60.1
95.2	46.7	343.5	51.2	370.0	98.5	328.8	476.7	396.0	60.1
95.5	46.7	343.5	50.8	370.0	98.5	329.4	477.0	394.5	60.1
94.0	46.7	343.5	50.9	369.9	98.3	330.0	478.2	395.3	60.1
95.2	46.5	343.5	51.2	369.9	98.4	329.4	477.3	395.3	60.2
95.2	46.8	343.5	50.8	370.0	98.5	329.4	476.7	396.0	60.1
95.2	46.1	343.5	50.5	370.0	98.5	329.4	477.0	395.3	60.0
94.9	46.6	343.5	50.7	370.0	98.4	330.0	477.9	394.5	60.1
94.9	46.5	343.5	50.7	370.0	98.3	329.4	478.2	395.3	60.1
95.2	46.6	343.5	51.0	370.0	98.3	329.4	477.9	395.3	60.1
95.2	46.7	343.5	50.7	369.9	98.4	329.4	477.0	395.3	60.1

AVERAGE VALUE:

95.2	46.6	343.5	50.9	369.9	98.5	329.3	477.4	395.4	60.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.27	0.23	0.00	0.17	0.04	0.07	0.31	0.54	0.51	0.02

Line# 1 Col# 1
Line# 4 Col# 2
Line# 11 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 22

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
97.4	50.9	322.6	44.7	328.4	72.2	231.0	479.1	280.5	60.3
96.4	52.2	322.5	43.4	328.5	72.2	231.0	479.1	280.5	60.3
95.5	53.5	322.6	48.3	328.5	71.8	231.0	480.0	279.8	60.3
95.5	55.1	322.5	48.2	328.5	71.5	229.8	478.8	279.0	60.1
95.5	53.1	322.5	47.0	328.5	71.2	229.2	478.8	279.0	59.9
96.7	51.0	322.5	41.6	328.5	71.0	228.6	480.0	277.5	59.8
96.4	51.8	322.5	44.7	328.5	72.0	229.2	478.5	279.0	59.9
96.1	52.4	322.5	45.1	328.4	72.3	230.4	478.8	279.8	60.0
96.7	52.5	322.5	45.3	328.5	72.5	231.0	478.8	280.5	60.1
95.8	56.4	322.5	51.2	328.4	72.3	231.0	479.7	279.8	60.2
96.1	52.4	322.5	42.5	328.5	72.5	230.4	478.8	279.0	60.3
96.4	53.2	322.5	45.5	328.4	72.5	231.0	478.8	281.3	60.3
95.5	55.1	322.5	48.9	328.4	72.1	229.8	478.8	279.8	60.3
95.8	53.3	322.5	46.3	328.4	71.5	230.4	480.0	278.3	60.1
96.7	53.6	322.5	45.3	328.5	71.1	229.8	480.0	278.3	60.0
96.1	52.4	322.5	47.4	328.4	71.0	229.8	480.0	277.5	59.9
95.2	53.3	322.5	47.4	328.5	71.4	228.6	478.5	278.3	59.8
95.5	55.0	322.5	48.4	328.5	72.2	230.4	480.0	278.3	59.9
96.7	53.7	322.5	48.3	328.4	72.6	230.4	479.4	279.0	60.0
96.7	53.8	322.5	47.2	328.4	72.7	230.4	480.3	279.0	60.1

AVERAGE VALUE:

96.2	53.2	322.5	46.3	328.5	71.9	230.2	479.3	279.2	60.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.50	1.05	0.01	1.90	0.03	0.51	0.65	0.56	0.83	0.14

Line# 1 Col# 3
Line# 3 Col# 3
Line# [illegible] Col# 2
Line# 14 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 4

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 23

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
87.8	32.5	319.9	66.0	324.6	78.3	229.9	480.0	278.3	60.[illegible]
89.4	33.9	319.8	67.0	324.6	78.1	230.4	479.7	279.8	60.3
89.1	32.2	319.9	63.3	324.5	78.1	229.8	478.5	279.8	60.2
88.1	32.7	319.9	66.9	324.5	77.5	229.2	480.0	278.3	60.2
89.7	33.1	319.9	65.8	324.5	77.2	229.2	479.1	279.0	60.1
90.0	32.5	319.9	64.4	324.5	76.7	229.2	480.0	278.3	59.9
89.7	32.7	319.9	65.5	324.5	77.0	228.0	478.5	278.3	59.8
89.7	32.5	319.9	65.3	324.6	76.7	229.2	480.0	277.5	59.8
87.2	33.7	319.9	69.8	324.6	77.4	227.4	478.5	277.5	59.9
87.8	32.9	319.8	64.5	324.6	77.7	228.6	480.0	277.5	60.0
88.7	33.7	319.8	69.3	324.6	78.0	228.6	479.4	277.5	60.0
90.9	33.7	319.8	68.1	324.6	78.1	229.8	480.0	278.3	60.1
89.1	33.9	319.8	66.4	324.5	78.3	229.2	478.5	279.8	60.2
89.7	31.5	319.8	64.1	324.5	78.0	229.8	480.0	279.0	60.3
90.0	34.2	319.8	65.4	324.5	77.8	229.8	478.5	279.0	60.2
88.4	34.3	319.8	68.6	324.5	77.2	229.2	479.7	278.3	60.2
89.4	33.8	319.8	65.3	324.4	76.8	228.6	478.8	279.0	60.0
89.4	32.1	319.8	63.0	324.5	76.5	229.2	480.0	277.5	59.9
89.7	33.6	319.8	64.2	324.6	76.6	229.6	478.8	277.5	59.9
89.4	32.6	319.8	64.3	324.7	76.5	228.0	480.0	276.9	59.9

AVERAGE VALUE:

89.1	33.1	319.8	65.9	324.5	77.4	229.1	479.4	278.3	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.69	0.69	0.03	1.52	0.04	0.59	0.58	0.60	0.70	0.14

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS OF POOR QUALITY

RUN NUMBER 24

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
88.1	19.9	317.6	79.2	323.7	77.5	228.6	479.4	278.3	60.2
88.1	20.1	317.6	81.0	323.7	76.4	228.0	480.6	276.8	60.1
87.8	19.5	317.6	80.8	323.7	76.1	227.4	479.4	276.0	59.9
86.9	19.4	317.5	77.9	323.8	76.1	226.8	479.4	276.0	59.8
88.1	19.3	317.5	77.3	323.8	75.8	226.8	479.4	276.8	59.7
86.9	19.7	317.5	81.4	323.8	76.6	227.4	480.6	275.3	59.8
87.2	20.3	317.4	81.8	323.7	77.6	228.0	479.4	277.5	59.9
87.2	19.4	317.4	79.0	323.8	77.9	228.0	479.4	277.5	60.0
87.5	20.4	317.4	82.2	323.7	78.1	228.6	479.7	278.3	60.1
87.5	19.9	317.4	81.4	323.7	78.2	229.2	480.0	277.5	60.2
87.5	19.7	317.4	81.2	323.7	77.9	229.2	480.0	277.5	60.3
87.2	20.2	317.4	82.2	323.7	77.9	229.2	480.0	277.5	60.2
89.1	19.7	317.4	77.2	323.7	77.4	228.6	480.0	277.5	60.2
88.1	20.3	317.4	81.6	323.7	77.1	228.6	479.7	277.5	60.1
88.1	19.6	317.4	77.6	323.7	76.6	228.0	479.4	276.8	60.0
87.8	19.5	317.4	79.4	323.7	76.3	227.4	479.1	276.8	59.9
87.8	20.1	317.4	80.0	323.8	76.1	228.0	480.3	276.0	59.9
88.4	19.6	317.4	77.2	323.8	76.4	227.4	479.4	276.8	59.8
87.8	20.3	317.4	80.6	323.9	76.5	228.6	480.9	276.0	59.9
87.8	19.7	317.4	79.8	323.9	77.3	228.0	479.4	277.5	59.9

AVERAGE VALUE:

87.8	19.8	317.4	79.9	323.8	77.0	228.1	479.8	277.0	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.41	0.30	0.07	1.47	0.04	0.71	0.5	0.42	0.68	0.14

Line# 13 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 25

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
87.8	19.6	317.2	80.5	324.0	76.2	228.0	480.0	276.0	59.9
88.1	19.5	317.2	79.3	323.9	77.6	228.6	479.7	278.3	60.0
88.1	19.5	317.2	80.6	323.9	77.9	228.0	479.1	278.3	60.1
87.5	20.1	317.2	82.1	323.8	77.8	229.2	480.6	277.5	60.2
87.2	19.7	317.2	81.0	323.8	77.7	228.6	479.1	279.0	60.3
87.2	19.9	317.1	81.8	323.7	77.9	229.2	479.4	278.3	60.3
88.4	19.8	317.2	80.9	323.7	77.3	229.8	480.6	277.5	60.2
87.2	20.3	317.1	81.9	323.7	77.0	228.6	479.4	278.3	60.1
87.8	19.2	317.2	79.5	323.7	76.7	228.0	479.4	278.3	60.0
87.8	19.7	317.2	79.8	323.7	76.3	228.0	480.3	277.5	59.9
87.2	19.5	317.1	81.5	323.7	76.4	227.4	479.1	276.8	59.8
87.5	19.3	317.1	79.1	323.7	76.4	228.6	480.9	276.0	59.8
87.2	20.3	317.1	82.6	323.7	77.5	228.0	479.7	278.3	59.8
87.8	19.5	317.1	80.2	323.8	78.0	229.2	480.0	276.8	59.9
87.8	19.8	317.1	80.2	323.7	78.5	229.2	480.0	278.3	60.1
87.5	20.1	317.1	81.5	323.7	78.4	229.8	480.9	277.5	60.2
86.9	20.5	317.1	83.4	323.7	78.6	229.8	479.7	279.0	60.2
88.1	19.8	317.1	80.3	323.7	78.4	229.8	480.9	278.3	60.3
87.2	19.8	317.1	80.6	323.6	78.2	229.8	479.7	279.0	60.2
86.6	19.8	317.1	81.5	323.6	77.5	229.2	480.6	277.5	60.1

AVERAGE VALUE:

87.6	19.8	317.2	80.9	323.8	77.5	228.9	480.0	277.8	60.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.39	0.26	0.03	0.90	0.06	0.64	0.66	0.53	0.72	0.14

Line# 1 Col# 5

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 26

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
85.4	12.9	313.8	93.5	321.9	78.7	226.2	483.0	272.3	59.7
84.1	13.2	313.8	94.9	322.0	80.5	227.4	483.0	273.0	59.9
84.4	13.1	313.8	96.3	321.9	81.1	226.8	481.8	274.5	60.0
84.1	12.9	313.8	93.2	321.9	81.3	227.4	481.8	274.5	60.1
84.1	13.0	313.8	95.8	321.9	81.1	227.4	482.4	273.8	60.1
84.4	13.2	313.8	95.9	321.9	81.0	228.0	482.1	274.5	60.2
85.7	13.0	313.8	93.1	321.9	81.2	228.0	481.5	275.3	60.2
85.1	13.1	313.8	94.1	321.9	80.6	227.4	481.8	275.3	60.2
85.1	13.2	313.8	95.2	321.9	79.3	228.0	483.3	273.8	60.1
85.1	12.9	313.8	92.1	321.9	79.3	227.4	483.0	273.9	60.0
95.7	12.8	313.8	91.3	321.9	78.8	226.8	483.0	273.0	59.9
84.7	12.9	313.8	94.3	321.9	79.0	225.6	481.8	273.0	59.9
85.4	12.9	313.8	91.4	321.9	79.0	226.2	481.5	273.8	59.7
84.4	13.1	313.8	95.4	321.9	79.8	226.8	482.1	273.0	59.8
83.8	12.7	313.8	93.1	321.9	80.6	226.2	482.1	273.0	59.9
84.1	12.9	313.8	95.2	321.9	81.0	227.4	483.0	273.0	60.0
84.1	13.6	313.8	97.2	321.9	81.3	227.4	482.7	273.0	60.1
84.4	13.0	313.9	92.4	321.8	81.3	228.0	483.3	273.8	60.2
84.4	13.2	313.9	95.7	321.8	81.6	227.4	482.4	275.3	60.2
84.4	13.1	313.9	94.3	321.7	81.2	228.0	483.3	274.5	60.2

AVERAGE VALUE:

84.7	13.0	313.8	94.2	321.9	80.4	227.2	482.4	273.8	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.47	0.16	0.04	1.37	0.04	0.86	0.57	0.56	0.72	0.15

Line# 2 Col# 5
Line# 17 Col# 2
Line# 20 Col# 5

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 27

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
84.1	13.0	313.8	95.0	321.9	80.9	227.4	481.5	275.3	60.2
84.7	12.7	313.8	93.2	321.9	79.4	226.8	481.8	273.0	60.0
84.4	12.7	313.8	94.3	321.9	79.4	226.8	481.5	273.0	59.9
85.1	12.4	313.8	93.1	321.9	79.3	226.9	482.4	273.0	59.8
84.7	12.8	313.8	93.3	321.9	79.3	226.2	481.2	273.0	59.8
84.4	12.6	313.8	93.6	321.9	79.9	227.4	483.0	272.3	59.8
84.4	12.9	313.8	94.6	321.9	80.9	226.8	481.8	273.8	59.9
83.5	13.5	313.8	96.4	321.8	81.1	227.4	482.7	273.0	60.0
84.4	12.9	313.7	94.3	321.8	81.4	228.0	482.7	274.5	60.1
84.4	13.2	313.7	95.8	321.8	81.5	228.0	482.4	275.3	60.2
83.8	13.2	313.8	95.8	321.8	81.7	228.0	481.2	275.3	60.2
84.1	12.6	313.7	95.4	321.7	81.3	228.0	482.1	274.5	60.2
85.4	12.8	313.7	93.9	321.6	81.0	228.0	481.5	275.3	60.2
83.8	12.8	313.7	92.4	321.7	80.2	227.4	482.7	273.0	60.1
84.1	12.6	313.7	91.2	321.7	79.8	227.4	482.4	273.0	60.0
84.4	13.0	313.7	95.2	321.7	79.9	226.2	481.2	273.8	59.9
84.7	12.9	313.7	94.6	321.7	79.7	226.8	482.4	273.0	59.9
84.1	12.8	313.7	92.0	321.7	79.9	226.2	481.8	273.0	59.8
84.1	13.0	313.7	95.6	321.8	80.4	226.2	481.2	273.0	59.8
83.8	13.1	313.7	96.0	321.7	81.2	227.4	482.7	273.0	59.8

AVERAGE VALUE:

84.3	12.9	313.7	94.3	321.8	80.4	227.2	482.0	273.6	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.35	0.21	0.04	1.16	0.06	0.74	0.56	0.54	0.84	0.14

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 28

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
108.7	107.2	334.2	15.9	336.5	63.2	228.6	478.8	278.3	60.4
109.1	105.1	334.2	17.0	336.6	62.4	228.0	478.5	277.5	60.0
109.1	102.7	334.2	17.7	336.7	62.4	228.6	478.5	277.5	60.0
109.4	100.3	334.2	15.2	336.7	62.4	228.0	478.5	276.8	60.0
108.4	105.7	334.2	17.6	336.7	62.9	227.4	478.2	276.8	60.0
109.1	105.0	334.2	16.8	336.7	63.2	229.2	478.8	278.3	60.2
106.6	112.5	334.2	16.2	336.6	63.2	227.4	479.4	276.8	60.2
109.7	105.0	334.2	17.7	336.6	63.5	229.8	478.8	278.3	60.3
108.1	103.2	334.2	16.2	336.6	63.4	229.8	479.4	277.5	60.5
108.4	106.3	334.2	16.9	336.6	63.0	229.8	479.4	278.3	60.5
107.5	104.5	334.2	16.3	336.7	62.4	228.6	478.8	277.5	60.3
108.7	104.9	334.2	15.5	336.6	62.1	227.4	478.5	276.8	60.0
108.4	103.0	334.2	16.9	336.6	62.1	226.8	478.5	276.9	59.9
108.7	103.9	334.2	15.4	336.5	63.4	228.0	480.0	276.8	60.0
108.7	107.7	334.2	17.5	336.6	63.7	229.8	478.8	276.8	60.3
109.1	107.1	334.2	16.6	336.6	63.7	229.8	479.1	279.0	60.5
108.7	108.1	334.1	16.9	336.7	63.6	229.2	478.5	279.0	60.4
108.4	101.2	334.2	14.4	336.7	63.2	229.8	478.5	279.0	60.[illegible]
108.4	106.2	334.2	16.3	336.6	62.5	228.6	478.5	278.3	60.3
108.7	101.5	334.2	15.0	336.5	61.8	228.6	480.0	276.0	60.0

AVERAGE VALUE:

108.6	105.1	334.2	16.4	336.6	62.9	228.7	478.9	277.6	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.44	2.04	0.03	0.71	0.04	0.50	0.79	0.41	0.77	0.18

Line# 7 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 29

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
109.7	102.7	334.4	16.2	336.8	62.6	229.2	478.8	279.0	60.5
108.4	102.1	334.4	15.3	336.9	62.2	227.4	478.5	276.0	59.7
109.4	105.9	334.4	17.8	336.8	63.8	228.6	478.8	278.3	60.1
108.7	106.1	334.4	18.0	336.9	63.6	229.8	480.0	278.3	60.4
108.7	105.7	334.4	16.7	336.9	63.5	230.4	478.8	279.8	60.6
109.7	102.2	334.4	16.0	336.9	62.7	229.8	480.3	279.0	60.6
108.4	106.2	334.4	17.3	336.8	61.8	228.6	478.8	279.3	60.3
109.7	104.9	334.4	15.7	336.7	61.1	228.0	478.8	275.3	60.0
110.0	110.2	334.4	17.4	336.7	60.9	227.4	478.8	276.0	59.8
110.9	105.2	334.4	15.6	336.8	63.3	229.2	480.0	278.3	60.0
108.4	108.3	334.4	16.5	336.9	63.7	230.4	478.5	279.8	60.5
109.4	105.2	334.4	16.1	337.0	63.0	229.8	479.5	279.8	60.6
109.1	100.1	334.4	16.7	337.0	62.0	229.8	480.0	278.3	60.5
109.4	100.6	334.4	16.3	337.0	61.2	228.6	480.0	277.5	60.3
110.3	104.0	334.4	16.0	336.9	60.8	227.4	479.4	276.8	60.0
110.6	107.8	334.3	17.4	336.9	60.9	226.2	478.8	276.0	59.7
109.4	105.2	334.3	16.7	336.9	63.2	229.2	480.3	278.3	60.1
109.1	102.3	334.3	17.0	337.0	63.3	230.4	478.8	279.0	60.5
108.7	105.2	334.3	17.8	337.0	62.9	229.8	479.7	279.0	60.5
108.4	102.6	334.4	17.0	336.9	62.2	228.6	478.5	279.0	60.4

AVERAGE VALUE:

109.3	104.6	334.4	16.7	336.9	62.4	228.9	479.2	278.1	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.57	2.04	0.04	0.64	0.05	0.98	0.96	0.61	1.09	0.26

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 30

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
101.7	79.9	330.1	49.0	336.2	83.1	303.0	458.7	380.3	59.7
98.6	85.4	330.1	55.5	336.0	92.4	310.8	457.2	392.3	60.6
100.1	93.6	330.0	53.8	336.0	89.0	310.8	458.1	392.3	60.7
99.8	83.3	330.1	50.5	336.0	86.2	309.6	457.5	390.8	60.2
99.5	79.6	330.0	47.4	336.0	84.8	308.4	457.2	388.5	59.9
100.1	80.0	330.1	47.3	336.0	84.0	305.4	457.2	386.3	59.4
101.1	79.9	330.1	48.3	336.1	89.5	307.2	457.5	388.5	59.4
99.5	86.4	330.1	56.4	336.1	90.2	309.6	457.9	388.5	59.7
99.5	82.9	330.1	51.3	336.1	90.4	309.6	457.5	389.3	60.1
98.6	84.4	330.1	53.9	336.1	90.5	310.2	457.5	391.5	60.3
98.9	83.3	330.1	52.4	336.0	90.4	310.2	457.5	391.5	60.4
100.1	84.3	330.1	53.8	336.0	89.6	310.8	457.2	392.3	60.5
100.1	83.4	330.1	51.0	336.0	88.5	309.6	456.9	390.8	60.4
99.8	83.6	330.1	51.1	336.0	87.4	309.6	457.2	390.0	60.2
100.1	82.4	330.1	48.6	336.0	86.3	307.8	457.5	389.3	60.0
100.1	79.6	330.1	47.3	336.0	85.2	307.8	458.1	386.3	59.7
101.1	80.9	330.1	49.8	336.1	95.2	306.6	457.5	386.3	59.3
99.2	82.5	330.1	51.2	336.1	89.2	307.8	457.5	387.8	59.6
99.2	94.2	330.1	56.7	336.1	90.2	309.0	458.7	388.5	59.9
100.4	84.5	330.1	51.2	336.0	90.5	310.2	457.8	390.0	60.1

AVERAGE VALUE:

99.9	82.7	330.1	51.3	336.1	88.1	308.7	457.6	389.0	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.65	1.68	0.04	2.33	0.04	2.29	1.56	0.36	2.05	0.35

Line# 1 Col# 7
Line# 19 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 31

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
101.1	83.4	331.3	49.5	336.3	87.3	307.9	459.0	385.5	60.5
102.3	79.6	331.3	45.9	336.3	82.4	302.4	459.0	380.3	59.4
102.0	81.3	331.3	47.2	336.4	86.3	302.4	458.1	381.0	59.5
101.1	83.9	331.4	50.5	336.4	86.8	303.6	458.7	381.8	59.8
100.4	81.7	331.3	48.0	336.4	87.8	304.2	457.8	384.0	60.0
100.4	83.4	331.3	48.4	336.3	87.9	301.2	456.9	384.9	60.2
100.1	83.6	331.3	48.4	336.3	87.8	306.0	457.5	385.5	60.4
101.1	83.6	331.4	50.2	336.3	87.3	306.0	458.4	384.0	60.5
100.7	83.6	331.3	48.0	336.3	86.1	306.0	458.7	384.8	60.5
100.7	81.1	331.3	46.1	336.3	84.7	304.8	458.4	384.0	60.3
101.7	81.9	331.3	46.3	336.3	83.7	303.6	457.8	382.5	60.0
101.4	80.4	331.4	46.6	336.4	82.4	303.6	458.4	380.3	59.7
101.7	80.1	331.4	46.8	336.4	82.2	301.2	457.5	380.3	59.4
101.1	81.7	331.4	48.3	336.4	86.5	304.2	457.5	381.8	59.6
100.1	82.8	331.4	48.5	336.5	87.2	304.8	458.1	381.8	59.9
101.4	85.0	331.4	49.1	336.5	87.7	306.0	458.1	383.3	60.2
101.4	82.7	331.4	51.3	336.3	87.7	306.0	457.9	384.8	60.3
99.8	85.1	331.4	48.4	336.3	87.3	305.4	457.8	385.5	60.5
100.7	81.8	331.3	49.4	336.4	86.4	305.4	457.8	385.5	60.4
101.1	82.0	331.4	44.8	336.3	85.4	304.8	457.8	384.0	60.3

AVERAGE VALUE:

101.0	82.4	331.3	48.1	336.4	86.0	304.5	458.1	383.3	60.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.49	1.27	0.04	1.30	0.05	1.55	1.38	0.44	1.65	0.34

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 32

Pl	Mf	Tf	Mv	Tv	Tl	kW	volts	amps	freq
92.1	48.5	328.1	75.9	332.2	99.8	309.0	457.2	388.5	59.7
93.4	45.2	328.0	77.2	332.1	100.1	309.0	458.1	388.5	59.7
92.7	48.0	328.0	76.4	332.1	99.9	309.0	458.4	388.5	59.7
93.4	48.0	328.0	77.7	332.1	99.8	309.6	459.3	388.5	59.7
92.7	48.1	328.1	74.2	332.1	100.0	309.0	458.7	387.8	59.6
91.8	48.4	328.0	77.5	332.1	99.7	307.8	456.9	387.8	59.6
91.5	47.7	328.0	75.5	332.1	99.9	307.8	457.5	387.8	59.6
93.4	48.3	328.1	74.9	332.1	99.9	308.4	458.7	388.5	59.6
92.4	48.0	328.1	76.6	332.1	99.8	307.8	457.2	388.5	59.5
92.1	47.5	328.1	74.8	332.1	99.9	303.6	457.5	384.8	59.8
92.4	48.3	328.1	75.9	332.1	99.7	305.4	458.7	383.3	59.9
93.4	48.0	328.1	75.9	332.1	100.0	305.4	457.2	384.8	60.1
93.1	48.5	328.1	77.2	332.1	99.8	305.4	458.1	384.8	60.2
91.5	48.4	328.1	77.1	332.1	100.1	306.0	457.2	384.8	60.3
92.1	46.5	328.1	75.1	332.1	100.0	306.0	457.2	385.5	60.3
93.1	46.3	328.1	74.8	332.1	99.8	309.6	452.1	394.5	60.3
93.7	44.8	328.1	73.1	332.1	99.8	309.6	453.3	393.0	60.2
92.7	44.4	328.1	78.2	332.1	100.0	309.0	452.1	393.0	60.2
92.4	44.9	328.1	76.9	332.0	100.1	307.8	452.1	390.8	60.1
92.4	47.4	328.2	76.5	332.0	99.9	308.4	453.9	391.5	60.1

AVERAGE VALUE:

92.6	47.3	328.1	76.1	332.1	99.9	307.7	456.6	388.2	59.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.52	1.14	0.05	1.06	0.04	0.10	1.43	1.94	2.31	0.27

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS OF POOR QUALITY

RUN NUMBER 33

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
92.4	43.9	328.2	80.7	331.9	100.1	307.2	452.1	391.5	59.6
93.4	43.6	328.1	77.2	331.8	99.8	307.8	454.2	390.0	59.4
91.5	44.9	328.1	77.5	331.8	100.0	306.0	451.9	390.0	59.3
93.4	44.6	328.1	79.3	331.9	100.1	306.0	451.8	390.8	59.3
91.2	44.9	328.0	79.5	331.8	99.9	306.0	451.5	390.0	59.3
91.8	43.3	328.0	72.9	331.9	99.9	306.0	451.5	390.0	59.4
93.1	45.3	328.0	79.7	331.7	100.2	305.4	451.5	390.0	59.3
91.2	44.3	328.0	75.6	331.7	99.8	304.8	451.5	388.5	59.2
90.9	41.9	328.0	74.8	331.6	99.9	304.8	451.5	389.3	59.1
91.5	43.3	328.0	77.4	331.6	100.0	304.2	452.4	387.8	58.9
91.8	43.8	328.0	79.4	331.4	100.1	304.2	452.1	386.3	58.8
91.5	42.4	327.9	75.1	331.4	100.2	304.2	452.1	386.3	58.6
91.5	42.3	328.0	77.7	331.3	100.1	303.0	453.0	385.5	58.5
92.4	42.9	327.9	79.1	331.2	99.9	302.4	451.5	386.3	58.4
91.2	43.9	327.9	75.1	331.2	99.9	301.8	451.8	385.5	58.2
91.8	43.3	327.9	77.7	331.2	100.0	303.0	452.7	385.5	58.2
91.2	43.9	327.9	76.9	331.1	100.0	301.9	451.5	384.9	58.0
91.5	42.1	327.9	76.3	331.0	100.0	325.8	450.0	420.8	57.9
92.7	43.0	327.9	74.5	330.9	100.0	283.8	429.9	379.5	57.5
91.2	42.7	328.0	76.9	330.9	99.8	287.4	440.7	375.8	58.2

AVERAGE VALUE:

91.9	43.5	328.0	77.2	331.5	100.0	303.8	450.3	388.7	58.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.62	0.78	0.05	1.64	0.29	0.09	4.33	3.02	4.41	0.54

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Line#  1 Col#  3
Line# 18 Col#  7
Line# 19 Col#  7
Line# 20 Col#  7
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Number of data sets for which the deviation exceeds 3X the average deviation: 4

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 34

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
135.9	104.9	364.5	29.5	368.8	69.5	421.8	459.6	519.0	60.5
134.9	105.4	364.4	30.3	368.7	69.6	421.2	461.1	519.0	60.3
134.3	104.2	364.5	29.4	368.8	69.9	420.6	459.9	520.5	60.3
135.8	105.2	364.4	29.3	368.8	69.9	420.0	459.9	519.8	60.4
135.5	105.7	364.4	29.6	368.8	69.9	421.2	459.9	520.5	60.4
133.4	104.9	364.4	29.7	368.8	70.0	420.0	459.6	520.5	60.4
134.6	106.4	364.4	29.9	368.8	70.1	421.2	459.6	521.3	60.4
134.6	105.2	364.4	29.5	368.8	70.1	[illegible]	459.9	520.5	60.5
134.6	108.1	364.4	30.4	368.8	70.2	423.6	459.9	525.0	60.1
134.0	105.5	364.4	29.8	368.8	70.5	424.2	459.9	523.5	60.0
135.2	106.7	364.4	29.5	368.8	71.7	425.4	460.2	526.5	60.1
132.4	109.6	364.3	31.0	368.8	72.2	[illegible]	459.9	525.8	60.3
133.4	106.7	364.4	30.2	368.7	72.5	426.0	461.1	525.0	60.5
134.3	108.8	364.3	30.6	368.7	72.5	426.0	460.2	526.5	60.6
131.5	108.7	364.3	30.7	368.8	72.7	427.2	462.0	527.3	60.7
135.5	107.4	364.3	29.9	368.7	72.6	424.2	466.5	519.8	60.9
134.0	108.5	364.3	30.7	368.7	71.7	423.0	465.3	519.8	60.9
134.6	107.9	364.3	29.8	368.7	70.5	423.0	465.6	518.3	60.8
135.2	106.2	364.3	29.9	368.7	69.5	422.4	465.3	517.5	60.5
136.7	104.6	364.2	29.3	368.7	68.6	421.2	465.3	516.8	60.2

AVERAGE VALUE:

134.5	106.5	364.4	29.9	368.7	70.7	423.0	461.5	521.6	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.89	1.35	0.04	0.42	0.03	1.09	1.86	2.08	2.81	0.20

Line# 15 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 35

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
131.5	107.7	364.0	30.3	368.6	70.8	420.0	466.5	514.5	61.0
134.6	103.6	364.1	29.0	368.6	70.5	420.0	467.4	512.3	60.5
135.8	106.2	364.1	29.8	368.6	70.8	419.4	466.8	514.5	60.6
134.9	107.1	364.1	29.8	368.5	70.6	420.0	466.8	513.8	60.7
135.5	106.0	364.2	29.6	368.6	70.6	420.0	468.0	513.8	60.8
134.6	105.5	364.2	29.3	368.6	69.9	420.0	466.[illegible]	512.9	60.8
135.2	104.8	364.2	29.6	368.6	69.5	420.0	467.1	513.0	60.6
136.4	101.6	364.2	29.0	368.5	68.9	418.2	466.5	511.5	60.4
136.1	103.3	364.2	29.6	368.6	68.0	417.6	468.3	510.9	60.2
134.3	103.3	364.2	28.8	368.6	68.0	417.0	467.1	510.0	60.0

AVERAGE VALUE:

134.9	104.9	364.1	.5	368.5	69.9	419.2	467.1	512.8	60.5

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.92	1.59	0.[illegible]	0.37	0.03	0.93	0.97	0.46	1.32	0.24

Line# 1 Col# 1
Line# 2 Col# 5

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 26

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
127.5	35.8	348.9	89.1	354.9	69.5	418.9	468.0	513.0	60.9
128.4	35.3	348.9	87.4	355.1	69.5	421.9	461.7	521.3	60.7
130.0	35.9	348.8	88.4	355.2	68.5	420.6	461.4	519.8	60.4
129.1	34.7	348.8	85.8	355.2	68.4	419.4	462.3	517.5	60.1
127.5	36.5	348.9	90.2	355.3	70.5	420.0	462.9	518.3	60.1
128.4	36.9	348.8	92.1	355.3	70.9	421.8	461.7	519.8	60.4
127.5	35.2	348.7	89.6	355.3	70.8	421.8	463.2	519.8	60.5
127.8	35.8	348.7	88.1	355.2	70.7	420.0	461.4	519.8	60.6
128.7	36.9	348.9	89.8	355.2	69.9	421.8	462.9	520.5	60.6
129.7	35.5	348.8	89.7	355.2	69.2	420.6	462.6	518.3	60.4

AVERAGE VALUE:

128.5	35.9	348.8	89.0	355.2	69.8	420.7	462.8	518.8	60.5

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.71	0.56	0.04	1.27	0.06	0.77	0.91	1.15	1.62	0.19

Line# 1 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 37

Pl	Mf	Tf	Mv	Tv	Ts	kW	volts	amps	freq
127.8	34.7	349.2	90.7	354.9	70.3	418.8	466.5	512.3	60.6
127.8	34.9	349.1	90.4	355.0	70.1	417.0	466.5	510.8	60.5
127.2	33.6	349.1	87.2	355.0	70.0	417.6	466.8	510.0	60.5
128.4	35.0	349.0	89.7	355.0	69.6	417.6	466.5	512.3	60.5
127.5	34.0	349.0	87.9	355.0	69.4	417.0	467.7	510.8	60.5
128.1	33.4	349.0	86.3	355.0	69.5	416.4	466.5	510.8	60.4
128.1	34.6	348.9	89.1	355.0	71.6	422.4	467.4	516.0	60.1
127.2	34.7	349.0	89.0	355.0	71.8	421.2	466.9	517.5	60.3
127.5	35.3	348.9	89.6	355.0	71.7	422.4	466.8	518.3	60.4
126.6	34.7	348.9	90.1	354.9	71.7	422.4	466.5	517.5	60.5

AVEPAGE VALUE:

127.6	34.5	349.0	89.0	355.0	70.6	419.3	466.8	513.6	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.43	0.50	0.06	1.11	0.03	0.89	2.26	0.30	2.97	0.10

Line# 1 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 38

P1	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
138.6	73.5	355.3	49.9	357.2	80.2	520.2	461.7	639.8	60.0
139.2	72.1	355.3	49.5	357.1	80.5	522.0	462.0	639.0	60.1
139.8	70.2	355.3	47.4	357.1	80.7	521.4	461.7	639.0	60.0
138.3	72.2	355.3	50.5	357.1	82.1	522.0	461.4	639.8	60.1
138.0	74.3	355.3	50.7	357.2	82.0	519.0	468.3	632.3	60.4
138.6	75.9	355.3	50.0	357.1	81.7	520.8	467.7	634.5	60.7
138.9	74.7	355.3	51.1	357.1	80.5	517.8	467.4	629.3	61.0
140.4	72.5	355.3	47.8	357.1	77.1	514.2	468.6	626.3	60.6
140.1	71.6	355.3	46.9	357.2	76.0	512.4	467.1	624.0	60.0
141.1	69.8	355.3	47.3	357.2	78.4	513.0	468.0	623.3	59.7

AVERAGE VALUE:

139.3	72.7	355.3	49.1	357.1	79.9	518.3	465.4	632.7	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.85	1.53	0.01	1.42	0.05	1.66	3.14	2.95	5.70	0.32

Line# 3 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 39

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
140.1	71.0	355.4	48.9	357.5	79.5	514.8	468.9	625.5	59.9
140.4	72.3	355.4	49.4	357.5	79.6	515.4	467.4	627.8	60.3

AVERAGE VALUE:

140.3	71.6	355.4	49.1	357.5	79.5	515.1	468.2	626.6	60.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.15	0.67	0.00	0.25	0.03	0.05	0.30	0.75	1.13	0.17

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 40

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
155.8	29.1	370.2	32.7	371.1	85.7	624.6	471.0	758.3	60.0
156.4	29.2	370.2	32.2	371.2	86.1	625.2	471.0	757.5	60.1
154.3	29.9	370.3	32.2	371.1	86.4	624.6	472.2	757.5	60.2
154.9	31.0	370.2	34.2	371.2	86.8	628.2	472.5	761.3	60.0
155.5	30.6	370.2	32.8	371.2	87.4	630.0	472.5	763.5	60.1
154.0	30.7	370.3	33.6	371.1	87.6	629.4	471.0	765.0	60.2
153.7	29.6	370.2	32.7	371.2	87.4	630.6	471.3	764.3	60.3
154.9	30.2	370.2	33.3	371.2	87.4	631.2	471.6	765.0	60.4
155.2	30.0	370.2	33.4	371.1	87.2	630.6	471.0	765.8	60.4
155.5	30.3	370.2	34.2	371.1	86.6	631.2	471.0	765.0	60.4

AVERAGE VALUE:

155.0	30.1	370.2	33.1	371.2	86.8	628.6	471.5	762.3	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.68	0.50	0.02	0.61	0.05	0.52	2.33	0.55	2.94	0.13

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL
OF POOR

RUN NUMBER 41

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
155.8	29.8	370.2	32.6	371.2	85.2	626.4	471.0	759.0	60.5
155.2	29.2	370.2	32.4	371.2	84.8	625.2	470.7	759.8	60.5
157.4	29.6	370.2	32.2	371.3	84.4	625.2	470.7	759.0	60.4
156.7	29.7	370.2	32.7	371.3	84.3	623.4	471.0	756.8	60.3
156.4	29.2	370.2	31.8	371.3	84.3	625.8	471.9	757.5	60.3
157.1	29.2	370.2	33.0	371.3	84.4	624.6	471.0	757.5	60.[illegible]
157.7	29.1	370.2	31.7	371.4	84.6	625.2	471.0	758.3	60.2
154.9	29.2	370.2	32.8	371.3	84.6	623.4	471.3	754.5	60.2
156.4	28.8	370.2	31.6	371.3	85.0	625.8	471.0	758.3	60.3
156.4	30.0	370.2	33.2	371.3	85.0	625.2	471.0	759.8	60.3

AVERAGE VALUE:

156.4	29.4	370.2	32.4	371.3	84.6	625.0	471.1	758.0	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.66	0.30	0.00	0.46	0.06	0.27	0.73	0.22	1.1[illegible]	0.08

Line# 5 Col# 8
Line# 8 Col# 9

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 42

P1	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
136.4	9.9	355.0	76.8	358.7	97.5	581.4	455.4	729.8	59.6
136.7	9.2	354.9	73.7	358.6	97.9	582.6	456.0	731.3	59.8
135.5	9.3	355.0	76.2	358.6	98.0	583.8	455.4	732.0	59.8
135.8	9.4	354.9	74.0	358.6	97.9	583.2	456.0	732.0	59.9
135.8	9.4	354.9	78.0	358.6	97.8	583.8	456.9	732.0	60.0
135.5	9.6	354.9	76.9	358.6	97.8	582.6	456.6	731.3	60.0
135.5	9.1	354.9	74.5	358.6	97.3	583.8	456.6	731.3	60.0
135.5	9.1	354.9	75.1	358.5	96.8	583.8	455.4	732.0	59.9
136.1	9.5	354.9	73.9	358.6	96.7	582.6	455.7	730.5	59.8
134.9	9.8	354.9	76.6	358.5	96.8	582.0	455.7	731.3	59.7

AVERAGE VALUE:

135.8	9.4	354.9	75.6	358.6	97.4	583.0	456.0	731.3	59.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.40	0.21	0.02	1.32	0.06	0.42	0.72	0.45	0.54	0.11

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 43

P1	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
137.1	9.6	354.2	79.7	358.8	97.2	582.6	455.4	731.3	59.7
135.8	9.8	354.2	79.4	358.8	97.1	584.4	456.9	732.0	60.0
135.8	9.2	354.2	75.5	358.8	97.2	585.0	456.6	732.8	60.0
134.9	9.5	354.1	77.2	358.6	97.1	585.0	456.6	731.3	60.0
137.1	9.6	354.1	76.3	358.6	96.4	583.8	456.3	731.3	59.9
135.8	9.4	354.1	75.0	358.5	96.4	582.6	455.7	731.3	59.8
136.1	9.4	354.1	75.3	358.6	96.4	582.0	455.4	730.5	59.7
135.8	9.3	354.0	73.7	358.5	96.5	581.4	455.7	729.8	59.6
135.8	9.8	354.0	74.4	358.6	97.4	581.4	456.9	729.0	59.5
135.5	9.9	354.0	77.5	358.5	98.5	582.6	456.0	730.5	59.6

AVERAGE VALUE:

136.0	9.6	354.1	76.4	358.6	97.0	583.1	456.2	731.0	59.8

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.46	0.18	0.04	1.64	0.11	0.47	1.18	0.51	0.81	0.17

Line# 10 Col# 6

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

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OF POOR QUALITY

RUN NUMBER 44

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
169.7	71.7	370.8	28.2	375.4	96.9	748.2	482.1	882.8	60.9
172.1	74.7	370.8	33.7	375.2	95.9	744.0	482.7	879.8	60.3
171.8	75.2	370.8	28.8	375.3	97.1	745.8	483.6	878.3	60.0
170.9	74.8	370.8	27.7	375.3	99.0	747.0	483.9	882.0	60.4
169.1	74.0	370.9	22.4	375.3	99.3	741.0	480.3	879.8	60.8
169.7	76.0	371.0	24.3	375.3	98.0	742.8	479.1	884.3	61.2
170.9	71.2	371.0	26.8	375.2	92.9	753.0	486.0	883.5	60.6
172.1	70.6	371.0	27.2	375.3	94.2	742.2	482.7	875.3	59.8
168.7	73.4	371.0	27.9	375.3	98.0	746.4	483.6	879.8	60.1
171.5	73.8	371.1	24.5	375.4	98.5	753.6	485.4	885.8	60.4

AVERAGE VALUE:

170.7	73.5	370.9	27.2	375.3	97.0	746.4	482.9	881.1	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.10	1.43	0.07	2.13	0.06	1.60	3.24	1.56	2.55	0.33

Line# 2 Col# 4

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 45

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
142.0	8.3	367.8	27.8	378.6	60.5	170.4	465.3	213.8	59.8
141.7	7.9	367.6	26.7	378.5	60.5	169.8	463.8	213.8	59.7
142.3	7.9	367.5	27.8	378.6	60.6	169.8	463.8	213.8	59.8
141.7	8.1	367.5	27.5	378.6	60.7	169.2	463.5	214.5	59.7
142.3	8.2	367.5	27.1	378.5	60.5	169.2	464.4	213.8	59.7
141.1	8.0	367.4	26.5	378.5	61.5	172.2	463.5	219.8	59.5
139.8	8.3	367.4	27.5	378.5	62.7	174.0	465.3	219.8	59.6
140.4	8.4	367.3	28.3	378.5	63.3	173.4	464.4	218.3	59.6
137.4	8.3	367.3	28.0	378.4	64.0	173.4	463.8	219.8	59.6
139.8	8.3	367.3	28.5	378.3	64.6	172.8	463.8	220.5	59.7

AVERAGE VALUE:

140.8	8.2	367.5	27.6	378.5	61.9	171.4	464.2	216.8	59.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.18	0.17	0.13	0.50	0.08	1.41	1.74	0.55	2.85	0.08

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 46

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
122.9	9.4	360.8	31.5	376.4	86.3	172.2	464.4	217.5	59.1
120.4	9.9	360.7	32.9	376.3	90.4	171.6	464.4	217.5	59.2
120.1	9.8	360.6	32.5	376.2	91.5	171.0	464.1	217.5	59.1
120.1	9.9	360.4	31.9	376.2	93.6	172.2	465.3	216.8	59.1
118.3	10.0	360.4	31.8	376.2	95.6	171.6	464.1	218.3	59.0
119.2	10.0	360.3	32.7	376.3	96.8	171.0	464.1	216.8	59.0
115.8	10.0	360.2	32.9	376.2	97.9	171.0	464.1	216.0	59.0
116.1	10.0	360.1	32.9	376.2	99.8	171.6	465.3	216.8	59.0
116.7	9.8	360.1	33.2	376.2	99.8	171.0	465.3	216.0	58.9
117.1	10.1	360.0	33.2	376.1	99.6	171.0	465.3	215.3	58.9

AVERAGE VALUE:

118.7	9.9	360.4	32.6	376.2	95.1	171.4	464.6	216.8	59.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.38	0.13	0.21	0.50	0.07	3.73	0.42	0.53	0.69	0.07

Line# 1 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 47

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
142.3	8.4	383.6	13.3	394.1	52.5	333.6	474.9	402.8	60.4
143.2	8.2	383.6	13.3	394.2	52.5	333.6	475.2	402.0	60.4
142.9	8.2	383.6	13.3	394.1	52.7	333.6	474.9	402.0	60.4
142.6	8.2	383.6	13.4	394.1	52.6	333.6	474.6	402.8	60.5
143.5	8.0	383.6	12.8	394.1	52.6	333.6	474.0	403.5	60.4
143.2	8.3	383.6	13.4	394.1	52.8	333.0	474.0	402.8	60.3
142.9	8.5	383.6	13.2	394.2	52.6	330.0	474.3	398.3	60.5
143.8	8.2	383.5	12.7	394.2	51.8	329.4	474.0	398.3	60.6
145.7	8.2	383.6	13.1	394.1	51.3	329.4	474.0	397.5	60.5
144.4	8.3	383.5	12.9	394.2	50.4	328.2	475.5	396.0	60.4

AVERAGE VALUE:

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
143.5	8.2	383.5	13.1	394.2	52.2	331.8	474.5	400.6	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
0.73	0.11	0.02	0.21	0.04	0.61	2.04	0.48	2.46	0.06

Line# 9 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 48

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
141.1	8.2	383.6	13.0	394.1	53.2	334.2	471.0	408.0	60.3
141.1	8.2	383.6	13.2	394.1	53.4	334.2	471.3	407.3	60.3
141.1	8.3	383.6	13.3	394.1	53.7	331.8	476.7	399.8	60.4
141.4	8.3	383.6	13.6	394.1	53.9	333.0	476.4	399.8	60.6
142.[illegible]	8.2	383.6	13.0	394.1	53.0	332.4	[illegible]	400.5	60.6
142.9	8.2	383.6	13.3	394.1	52.2	332.4	[illegible]	398.[illegible]	60.5
144.4	8.2	383.6	13.1	394.1	51.3	330.6	476.7	399.8	60.4
144.7	8.1	383.6	13.2	394.1	51.3	330.6	476.7	399.0	60.2
143.2	8.3	383.6	13.2	394.1	51.2	330.0	476.4	398.3	60.2
144.4	8.2	383.6	13.3	394.1	51.7	331.8	477.9	398.3	60.3

AVERAGE VALUE:

142.7	8.2	383.6	13.2	394.1	52.5	332.1	475.8	400.9	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.27	0.05	0.01	0.12	0.01	0.92	1.14	1.85	2.70	0.11

Line# 1 Col# 3

Number of data sets for which the deviation
exceeds 2X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 49

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
142.6	8.8	369.3	43.4	380.6	78.6	333.0	471.6	405.0	60.1
142.6	8.8	369.3	43.1	380.6	79.1	332.4	470.4	406.5	60.1
144.4	8.9	369.3	43.7	380.6	78.8	333.6	471.6	405.8	60.0
142.3	8.8	369.3	43.8	380.6	79.0	333.6	471.0	405.0	60.0
143.8	9.0	369.3	43.0	380.6	79.1	333.6	471.9	405.0	60.0
143.2	8.8	369.3	42.7	380.6	79.1	333.6	471.6	405.8	60.0
142.3	8.9	369.3	43.6	380.6	79.1	333.6	471.6	405.8	60.1
142.6	8.8	369.3	42.9	380.6	79.2	333.6	471.6	405.8	60.0
143.5	8.8	369.3	42.7	380.6	79.3	333.6	471.9	406.5	60.0
142.3	8.6	369.3	43.0	380.6	79.3	333.0	471.6	405.0	60.0

AVERAGE VALUE:

143.0	8.8	369.3	43.2	380.6	79.0	333.4	471.5	405.6	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.63	0.07	0.04	0.34	0.03	0.15	0.34	0.31	0.48	0.02

Line# 2 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

C-5

RUN NUMBER 50

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
154.3	7.2	368.5	44.2	379.8	64.6	330.0	473.1	400.5	60.1
155.5	7.5	368.5	44.4	379.7	64.4	333.0	474.9	402.0	60.4
156.1	7.1	368.5	45.0	379.7	64.4	334.2	466.2	410.3	60.3
154.6	7.3	368.5	45.2	379.7	64.2	334.8	468.0	408.8	60.1
154.6	7.1	368.5	44.4	379.7	64.5	333.6	467.7	408.0	60.0
154.3	7.4	368.6	45.2	379.7	65.8	334.2	467.7	410.3	60.1
153.7	7.2	368.6	44.8	379.7	66.1	334.8	469.2	408.0	60.2
153.1	7.2	368.6	45.3	379.6	66.4	334.8	468.6	408.8	60.3
154.0	7.4	368.6	46.6	379.6	66.5	335.4	469.5	409.5	60.3
152.1	7.2	368.6	46.0	379.5	66.7	334.2	467.7	409.5	60.2

AVERAGE VALUE:

154.2	7.3	368.6	45.1	379.7	65.4	333.9	469.3	407.6	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.81	0.13	0.04	0.55	0.05	0.91	1.02	1.94	2.52	0.07

Line# 1 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 51

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
153.1	7.4	368.5	45.6	379.5	66.9	334.8	468.0	410.3	60.3
153.4	7.3	368.5	45.3	379.5	66.7	336.0	469.2	410.3	60.3
152.7	7.2	368.5	45.3	379.5	66.8	335.4	468.6	408.8	60.3
153.7	7.5	368.5	46.0	379.4	66.8	335.4	468.3	408.8	60.3
153.1	7.2	368.5	45.9	379.4	66.9	335.4	469.2	408.8	60.3
152.7	7.2	368.5	46.1	379.4	66.9	334.8	467.7	409.5	60.2
151.5	7.4	368.5	46.2	379.4	66.7	334.2	467.7	408.8	60.2
153.7	7.6	368.5	46.3	379.4	67.0	334.8	467.7	409.5	60.2
152.7	7.4	368.5	46.8	379.4	67.0	331.2	469.2	404.3	60.3
153.4	7.3	368.5	45.7	379.3	67.0	331.8	468.0	405.0	60.5

AVERAGE VALUE:

153.0	7.4	368.5	45.9	379.4	66.9	334.4	468.4	408.4	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.44	0.12	0.01	0.37	0.04	0.12	1.19	0.55	1.50	0.06

Line# 1 Col# 3
Line# 7 Col# 1
Line# 10 Col# 10

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

RUN NUMBER 52

Fl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
160.7	13.7	377.1	33.6	383.7	69.4	337.8	481.2	403.5	60.3
159.8	13.8	377.2	34.2	383.7	71.2	341.4	474.6	411.8	60.2
158.3	14.2	377.1	35.6	383.7	71.8	341.4	474.0	413.3	60.1
159.5	14.1	377.2	35.0	383.6	72.2	342.6	475.2	412.5	60.2
159.5	14.0	377.2	34.0	383.6	72.4	341.4	474.6	413.3	60.2
159.2	14.2	377.2	34.6	383.5	72.7	342.6	474.6	413.3	60.2
157.7	14.6	377.2	34.9	383.5	72.8	341.4	474.3	413.3	60.2
157.4	14.1	377.2	35.0	383.5	72.9	341.4	474.6	412.5	60.2
159.5	13.6	377.2	34.0	383.5	72.9	342.0	474.6	413.3	60.2
158.3	14.2	377.3	35.1	383.4	73.0	341.4	474.6	412.5	60.2

AVERAGE VALUE:

159.0	14.1	377.2	34.6	383.6	72.1	341.3	475.2	411.9	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.87	0.24	0.05	0.52	0.07	0.82	0.71	1.19	1.71	0.04

Line# 1 Col# 6

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 53

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
159.5	13.5	377.3	33.7	383.5	70.7	340.2	473.7	412.5	60.1
157.7	13.3	377.3	33.6	383.4	71.0	337.2	473.7	407.3	60.3
159.5	13.7	377.2	34.0	383.4	70.3	337.8	474.0	407.3	60.3
158.9	13.5	377.3	32.9	383.4	69.6	337.2	474.6	407.3	60.3
162.0	13.7	377.3	34.0	383.4	69.6	341.4	464.7	417.8	60.1
160.1	13.5	377.3	33.3	383.4	69.8	337.8	472.5	409.5	60.1
161.1	13.9	377.2	34.4	383.4	70.3	337.8	471.9	410.3	60.2
161.4	13.7	377.3	33.7	383.4	70.7	339.0	471.6	411.0	60.2
159.2	13.7	377.2	34.3	383.4	70.6	339.0	472.5	411.0	60.3
158.6	14.0	377.3	34.2	383.4	70.9	338.4	471.0	410.3	60.1

AVERAGE VALUE:

159.8	13.6	377.3	33.8	383.4	70.4	338.6	472.0	410.4	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.07	0.17	0.03	0.38	0.04	0.41	1.06	1.78	2.13	0.09

Line# 5 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 54

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
155.5	27.1	387.1	14.4	392.5	80.2	346.2	475.5	417.8	60.1
154.0	26.9	387.1	14.4	392.4	80.9	345.6	475.5	416.3	60.0
154.9	27.0	387.2	14.4	392.4	81.0	345.0	474.0	417.8	60.0
155.2	26.8	387.2	14.4	392.4	80.9	345.0	473.7	417.0	60.1
155.2	27.8	387.2	14.6	392.4	80.9	346.2	474.9	417.0	60.1
154.6	27.5	387.2	14.4	392.4	80.9	342.0	480.0	409.5	60.2
155.5	26.7	387.2	14.2	392.5	80.5	343.2	481.2	408.8	60.3
155.2	27.2	387.3	14.7	392.5	79.9	342.6	480.3	409.5	60.3
155.5	26.9	387.3	14.6	392.5	78.8	342.6	480.6	409.5	60.2
156.1	26.5	387.3	14.5	392.5	77.8	342.6	481.5	408.8	60.2

AVERAGE VALUE:

155.2	27.0	387.2	14.5	392.4	80.2	344.1	477.7	413.2	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.41	0.30	0.04	0.10	0.03	0.82	1.50	3.00	3.98	0.08

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 55

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
159.8	25.3	387.6	13.6	393.0	73.3	341.4	474.0	412.5	60.1
159.2	26.8	387.6	14.4	392.9	75.6	345.6	474.9	417.0	59.9
159.2	26.1	387.6	14.4	393.0	75.9	346.8	475.8	417.0	60.0
159.5	26.1	387.6	14.2	392.9	76.4	346.2	474.6	417.8	60.1
158.9	26.3	387.6	14.4	393.0	76.4	346.2	476.1	417.8	60.1
159.2	26.3	387.6	13.9	392.9	76.7	345.6	475.5	417.8	60.1
159.5	26.3	387.6	14.2	392.9	77.0	346.8	475.2	418.5	60.0
158.0	26.2	387.6	14.4	392.9	77.2	345.6	473.7	417.8	60.1
157.7	26.1	387.7	14.2	392.9	77.3	345.6	473.7	417.8	60.1
158.3	26.3	387.7	14.3	392.9	77.3	345.6	474.6	416.3	60.1

AVERAGE VALUE:

158.9	26.2	387.7	14.2	393.0	76.3	345.5	474.8	417.0	60.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.58	0.23	0.02	0.18	0.03	0.81	0.83	0.69	1.05	0.04

Line# 1 Col# 2
Line# 2 Col# 10

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 56

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
176.4	42.2	393.9	12.9	402.2	62.2	340.2	480.3	407.3	60.3
176.7	42.8	393.9	12.9	402.2	61.7	341.4	481.8	405.8	60.2
176.1	43.1	393.9	12.9	402.2	61.6	341.4	480.9	405.8	60.3
176.7	41.9	393.9	12.7	402.3	61.6	340.2	480.0	407.3	60.3
177.1	42.1	394.0	12.8	402.2	61.7	340.2	480.3	406.5	60.3
176.4	41.8	393.9	12.8	402.3	61.4	340.8	481.8	405.0	60.2
176.4	42.4	393.9	13.4	402.3	61.4	340.2	480.0	405.8	60.3
177.1	42.0	393.9	12.8	402.2	61.5	340.2	480.6	407.3	60.3
176.7	41.9	393.9	12.7	402.2	61.5	340.2	480.3	407.3	60.3
175.5	41.9	393.9	13.5	402.2	61.4	343.2	474.9	414.0	60.2

AVERAGE VALUE:

176.5	42.2	393.9	12.9	402.3	61.6	340.8	480.1	407.2	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.34	0.34	0.01	0.20	0.03	0.17	0.72	1.07	1.43	0.04

Line# 1 Col# 6
Line# 5 Col# 3
Line# 10 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

RUN NUMBER 57

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
166.6	44.6	394.0	12.9	401.8	69.2	348.0	474.0	420.8	60.3
167.8	45.8	394.0	13.4	401.8	68.8	344.4	474.6	414.8	60.2
168.1	44.6	394.0	13.7	401.8	68.8	344.4	474.0	417.0	60.3
167.8	44.3	394.0	13.5	401.8	68.1	344.4	474.0	416.3	60.4
170.0	43.9	394.0	13.5	401.8	67.2	345.0	474.0	416.3	60.4
169.7	43.8	394.0	12.8	401.8	66.3	345.6	474.6	416.3	60.3
171.8	43.4	394.0	13.8	401.8	65.7	345.0	475.2	416.3	60.2
171.8	44.1	394.0	14.0	401.9	65.5	345.0	475.2	415.5	60.3
170.6	43.3	394.0	13.0	401.9	65.5	345.0	474.0	416.3	60.3
171.2	43.2	394.0	13.4	401.9	65.5	344.4	474.3	416.3	60.2

AVERAGE VALUE:

169.5	44.1	394.0	13.4	401.8	67.1	345.1	474.4	416.6	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.56	0.57	0.03	0.29	0.04	1.36	0.67	0.41	0.93	0.05

Line# 1 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 58 ,

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
126.3	126.8	392.7	10.3	393.6	47.5	282.6	481.2	339.0	59.9
124.4	127.8	392.6	10.8	393.5	49.9	285.0	474.6	348.0	59.7
121.4	124.8	392.5	10.6	393.5	50.1	285.0	474.6	346.5	59.8
123.2	129.3	392.6	10.6	393.5	50.1	285.6	474.6	348.0	59.9
122.9	128.6	392.5	10.3	393.4	50.4	286.2	475.5	346.5	59.8
121.7	125.8	392.5	10.5	393.4	50.5	285.0	475.5	347.3	59.9
120.4	155.4	392.5	10.8	393.4	50.4	285.0	474.9	346.5	59.7
118.3	169.1	392.5	10.7	393.4	50.3	282.6	474.3	345.0	59.4
119.8	152.5	392.3	10.9	393.4	54.0	287.4	475.5	350.3	59.0
117.7	161.7	392.3	11.0	393.4	55.1	288.0	474.6	352.5	59.4

AVERAGE VALUE:

121.6	140.2	392.5	10.7	393.5	50.8	285.2	475.5	347.0	59.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

2.09	15.61	0.09	0.18	0.07	1.50	1.25	1.13	2.25	0.23

Line# 1 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 59

P1	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
137.7	8.5	391.0	28.6	393.2	40.1	294.6	477.6	355.5	61.7
133.1	8.1	391.0	31.3	391.7	40.8	286.8	478.5	346.5	59.4
130.9	8.1	391.0	26.9	391.6	41.9	289.8	477.6	351.0	60.2
136.1	7.4	391.0	31.2	391.4	42.1	295.2	477.6	357.8	61.4
143.2	8.0	391.0	32.4	391.1	34.7	294.6	477.6	355.5	61.7
144.4	7.0	391.0	38.8	[illegible].8	33.6	292.2	477.9	351.0	61.2
14[illegible].8	7.0	391.0	41.[illegible]	39[illegible]	32.8	288.6	477.6	349.5	60.5
135.2	7.3	391.0	34.[illegible]	390.[illegible]	38.2	286.2	478.2	345.8	59.2
129.4	7.6	391.0	30.1	389.9	40.6	282.6	477.6	341.3	59.5
130.6	7.5	391.0	29.5	389.[illegible]	41.1	286.8	480.0	344.3	60.2
131.5	6.8	391.0	29.9	389.6	41.3	289.2	478.5	348.8	61.2
136.1	7.2	391.0	34.6	38[illegible].3	36.3	288.6	477.3	348.0	61.6
140.7	6.7	391.0	36.8	389.0	34.4	286.2	477.3	346.5	61.0
141.4	6.3	391.0	39.4	388.8	33.4	283.8	477.3	343.5	60.4
137.7	5.6	391.0	36.8	388.5	33.4	282.0	478.8	339.0	59.4
130.6	3.8	391.0	32.6	388.3	38.5	282.0	477.3	340.5	59.7
128.7	4.1	390.9	32.0	388.1	40.2	283.2	477.3	341.3	59.8
130.0	2.7	390.8	33.7	387.8	40.8	286.2	477.9	344.3	60.4
129.7	2.4	390.7	35.3	387.6	40.6	287.4	477.3	346.5	60.9
130.6	0.0	390.6	37.7	387.4	40.1	288.6	478.5	347.3	61.3

AVERAGE VALUE:

135.1	6.1	390.9	33.6	389.7	38.2	287.7	477.9	347.2	60.5

AVERAGE ABSOLUTE VALUE OF DEVIATION:

4.57	1.80	0.07	3.18	1.29	2.91	3.18	0.52	3.97	0.72

Line# 10 Col# 8
Line# 19 Col# 3
Line# 20 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 60

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
117.7	3.0	386.3	38.8	383.5	42.8	283.8	478.2	343.5	60.2
129.1	0.0	385.8	36.4	383.0	41.7	292.2	479.4	351.8	60.9
130.9	1.9	385.6	36.8	383.0	40.7	292.8	479.4	352.5	61.1
130.9	2.0	385.5	36.4	383.0	39.5	291.6	479.1	351.8	61.0
130.9	3.7	385.4	36.4	382.8	38.3	289.8	478.2	350.3	60.6
129.1	0.0	385.4	36.3	382.7	37.7	286.2	477.3	345.9	59.8
128.1	0.0	385.4	37.1	382.6	41.3	287.4	478.2	347.3	59.6
127.2	4.2	385.3	37.6	382.6	41.6	289.8	477.9	349.5	60.3
126.0	2.0	385.2	37.7	382.5	41.6	291.0	477.6	351.0	60.7
126.6	0.0	385.2	37.1	382.5	41.0	290.4	477.6	351.0	60.6

AVERAGE VALUE:

127.6	1.7	385.5	37.1	382.8	40.6	289.5	478.3	349.4	60.5

AVERAGE ABSOLUTE VALUE OF DEVIATION:

2.62	1.35	0.24	0.59	0.23	1.27	2.22	0.61	2.36	0.40

Line# 1 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 61

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
123.2	52.8	381.6	35.1	379.9	43.8	287.4	477.9	347.3	59.9
126.3	46.0	381.9	34.2	379.9	42.0	288.6	478.8	348.8	60.2
127.2	38.7	382.0	34.0	380.0	41.2	287.4	477.9	348.0	60.0
126.6	62.6	382.0	34.7	380.0	41.3	287.4	478.5	346.5	59.8
126.0	44.0	382.0	34.5	379.9	41.6	287.4	479.1	347.3	59.7
126.6	32.5	382.0	34.2	380.0	42.6	288.0	477.6	348.8	59.9
127.5	25.5	382.0	33.7	380.0	43.0	290.4	477.9	350.3	60.4
127.8	34.5	382.1	34.0	380.0	42.8	291.0	477.6	352.5	60.7
126.6	30.9	382.1	34.3	380.0	42.1	291.0	477.6	351.8	60.7
126.6	39.5	382.2	34.7	380.0	41.2	285.6	477.9	345.8	60.6

AVERAGE VALUE:

126.4	40.7	382.0	34.3	380.0	42.2	288.4	478.1	348.7	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.77	8.52	0.10	0.34	0.03	0.70	1.46	0.43	1.73	0.33

Line# 1 Col# 1

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 62

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
132.7	36.3	382.6	33.2	380.6	40.4	293.4	473.7	357.8	60.5
131.2	26.8	382.6	33.0	380.6	40.8	292.8	472.8	357.0	60.2
131.5	26.3	382.6	32.3	380.6	40.7	292.8	472.5	358.5	60.3
131.8	31.4	382.6	32.7	380.6	40.8	292.8	472.5	358.5	60.4
130.6	28.7	382.6	32.4	380.6	40.8	293.4	473.4	357.0	60.4
130.3	28.3	382.6	32.2	380.6	40.8	292.8	473.4	357.8	60.5
130.9	34.6	382.6	33.5	380.6	40.5	292.2	472.5	358.5	60.3
132.4	30.8	382.6	33.2	380.6	40.2	292.2	472.8	356.3	60.3
131.2	38.3	382.6	33.2	380.6	40.2	291.6	472.8	356.3	60.1
132.1	31.9	382.6	32.2	380.6	40.2	289.8	472.2	356.3	59.8

AVERAGE VALUE:

131.5	31.3	382.6	32.8	380.6	40.5	292.4	472.9	357.4	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.65	3.16	0.01	0.43	0.03	0.23	0.74	0.38	0.83	0.16

Line# 1 Col# 3
Line# 10 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

RUN NUMBER 63

Pl	Mf	Tf	Mv	Tv	T8	kW	volts	amps	freq
134.0	35.6	377.3	32.1	380.7	40.2	290.4	478.8	350.3	60.4
137.1	34.2	375.6	32.1	380.7	36.9	283.8	477.9	342.0	59.9
135.9	35.2	375.3	30.4	380.8	38.1	284.4	477.6	342.8	60.0
135.8	33.3	374.9	30.6	380.8	38.9	285.0	478.2	344.3	60.2
134.9	35.6	374.6	31.2	380.8	38.9	286.2	478.5	344.3	60.6
135.8	35.4	374.3	32.1	380.8	38.9	286.8	477.9	345.8	60.8
135.5	36.5	374.1	32.8	380.8	38.4	286.2	479.1	345.8	60.8
136.1	35.7	373.8	32.4	380.7	37.6	288.6	473.7	351.8	60.6
137.7	33.9	373.4	32.0	380.7	37.0	286.8	473.1	350.3	60.1
137.7	35.9	373.1	30.5	380.7	37.0	285.0	473.7	348.0	59.7

AVERAGE VALUE:

136.0	35.1	374.6	31.6	380.8	38.2	286.3	476.9	346.5	60.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.87	0.81	0.91	0.73	0.03	0.89	1.46	2.01	2.85	0.32

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 64

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
110.3	9.2	354.4	41.3	377.6	51.6	280.9	473.7	343.5	59.5
110.9	8.1	354.3	42.3	377.4	50.4	281.4	473.7	344.3	59.7
110.9	7.6	354.3	42.6	377.3	50.6	280.8	473.7	345.0	59.7
111.2	7.6	354.2	43.9	377.2	50.6	281.4	473.1	345.0	59.7
110.3	7.9	354.2	43.6	377.2	50.5	282.0	473.7	344.3	59.7
110.6	8.1	354.2	42.7	377.1	50.4	282.0	474.9	343.5	59.7
109.7	7.2	354.1	42.4	377.0	50.5	281.4	474.0	342.8	59.5
109.4	7.6	354.1	42.1	377.0	50.4	280.2	474.3	341.3	59.2
107.8	7.7	354.1	41.3	377.0	53.2	276.6	473.7	338.3	59.3
107.8	8.0	354.1	41.3	377.0	53.5	278.4	474.6	338.3	59.6

AVERAGE VALUE:

109.9	7.8	354.2	42.3	377.2	51.2	280.5	473.9	342.6	59.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.97	0.23	0.07	0.69	0.16	0.96	1.26	0.41	2.01	0.15

Line# 1 Col# 3
Line# 9 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 65

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
109.7	7.6	353.3	42.1	376.7	51.6	278.4	480.0	333.8	59.4
107.2	8.2	353.1	43.4	376.6	52.2	279.6	479.7	336.0	59.9
108.1	7.9	353.1	43.2	376.5	52.0	279.6	480.0	336.0	59.8
108.1	8.0	353.1	42.9	376.5	51.5	279.0	480.6	336.0	59.8
109.7	7.9	353.1	42.4	376.5	51.3	278.4	480.9	334.[illegible]	59.6
107.8	7.3	353.0	41.3	376.5	51.3	277.9	480.0	333.[illegible]	59.4
107.8	7.7	353.0	41.7	376.5	51.4	277.2	480.0	33[illegible].9	59.2
107.2	7.0	353.0	42.2	376.5	53.0	277.2	479.7	335.[illegible]	59.3
107.8	7.7	353.0	43.1	376.5	53.4	278.4	480.0	335.3	59.5
106.9	7.6	353.0	43.2	376.5	53.8	279.0	480.0	336.8	59.7

AVERAGE VALUE:

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
108.0	7.7	353.1	42.5	376.5	52.2	278.5	480.1	335.1	59.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
0.69	0.25	0.05	0.61	0.06	0.73	0.67	0.26	0.93	0.19

Line# 1 Col# 3
Line# 5 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

RUN NUMBER 66

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
132.7	23.1	390.7	0.0	231.2	52.5	290.4	487.2	345.9	60.2
132.7	23.0	390.7	0.0	231.1	52.7	290.4	486.6	345.0	60.2
132.4	23.0	390.7	0.0	231.1	52.7	289.8	486.9	345.8	60.2
131.2	23.1	390.7	0.0	231.1	52.5	289.8	487.8	345.0	60.2
131.2	22.6	390.7	0.0	231.1	52.6	291.6	487.2	345.8	60.3
131.5	22.7	390.7	0.0	231.1	52.6	289.8	487.2	345.8	60.2
133.7	23.0	390.7	0.0	231.1	52.4	291.0	487.2	345.0	60.2
131.5	22.1	390.7	0.0	231.1	52.5	290.4	488.1	344.3	60.3
132.7	22.7	390.7	0.0	231.1	52.7	291.0	486.9	345.8	60.2
132.4	22.7	390.7	0.0	231.1	52.5	291.6	488.4	345.0	60.3

AVERAGE VALUE:

132.2	22.8	390.7	0.0	231.1	52.6	290.6	487.4	345.3	60.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.69	0.21	0.03	0.00	0.01	0.09	0.58	0.45	0.45	0.02

Line# 1 Col# 5
Line# 5 Col# 5
Line# 8 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

ORIGINAL PAGE IS
OF POOR QUALITY

RUN NUMBER 67

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
145.7	22.4	391.5	0.0	223.9	44.6	292.2	485.1	348.0	60.3
143.8	22.7	391.5	0.0	223.9	44.6	291.6	484.2	348.0	60.3
145.7	22.6	391.4	0.0	223.9	44.7	288.0	485.4	342.0	60.3
145.7	22.5	391.5	0.0	223.9	44.6	287.4	484.2	343.5	60.6
144.4	22.6	391.5	0.0	223.9	44.6	288.6	485.4	343.5	60.6
145.4	22.3	391.4	0.0	223.9	44.1	288.0	484.5	342.8	60.6
146.0	22.3	391.4	0.0	223.9	43.5	286.8	484.5	342.0	60.4
146.6	22.6	391.4	0.0	223.9	43.5	287.4	484.2	342.0	60.4
147.5	22.6	391.4	0.0	223.9	43.5	287.4	484.2	342.0	60.4
146.3	22.4	391.4	0.0	223.9	43.5	288.0	484.2	343.5	60.4

AVERAGE VALUE:

145.7	22.5	391.4	0.0	223.9	44.1	288.5	484.6	343.7	60.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.71	0.13	0.03	0.00	0.00	0.49	1.36	0.43	1.71	0.11

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 68

Pl	Mf	Tf	Mv	Tv	Ta	kW	volts	amps	freq
130.0	22.8	387.3	0.0	390.3	52.9	287.4	471.0	353.3	60.0
130.3	22.0	387.3	0.0	390.2	52.9	287.4	471.9	352.5	60.0
129.7	22.4	387.4	0.0	390.2	53.1	286.8	470.7	352.5	59.9
129.7	22.4	387.3	0.0	390.2	53.3	288.0	471.9	353.3	60.0
129.4	22.5	387.3	0.0	390.2	53.7	288.0	471.0	354.0	60.1
128.4	22.4	387.4	0.0	390.2	53.6	288.0	470.7	352.5	60.0
129.7	22.5	387.4	0.0	390.2	53.6	285.0	476.7	345.0	60.1
130.0	23.1	387.4	0.0	390.2	53.3	285.0	476.7	345.0	60.2
129.1	23.0	387.4	0.0	390.2	52.9	283.8	477.0	344.3	60.1
130.3	22.8	387.4	0.0	390.2	52.6	285.0	476.1	344.3	60.1

AVERAGE VALUE:

129.6	22.6	387.3	0.0	390.2	53.2	286.4	473.4	349.7	60.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.41	0.27	0.03	0.00	0.03	0.30	1.39	2.60	4.02	0.07

Number of data points for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 69

Pl	Mf	Tf	Mv	Tv	T%	kW	volts	amps	freq
124.7	127.7	387.6	0.0	390.4	56.0	284.4	476.4	345.0	60.0
124.4	126.9	387.6	0.0	390.5	55.6	283.8	476.7	343.5	60.0
125.1	126.6	387.6	0.0	390.4	55.6	284.4	477.6	343.5	59.9
126.0	127.4	387.6	0.0	390.5	55.8	283.8	476.1	344.3	59.8
124.7	127.4	387.6	0.0	390.4	55.7	283.2	476.1	343.5	59.9
123.8	127.5	387.6	0.0	390.4	55.8	283.2	476.1	343.5	59.8
125.4	127.1	387.6	0.0	390.5	56.2	284.4	476.1	344.3	59.9
124.4	127.7	387.6	0.0	390.5	56.3	283.8	476.1	344.3	60.0
124.7	126.9	387.6	0.0	390.5	56.4	283.8	476.1	344.3	50.0
124.1	126.6	387.6	0.0	390.5	56.2	283.2	476.1	344.3	59.9
AVERAGE VALUE:									
124.7	127.2	387.6	0.0	390.5	55.9	283.8	476.3	344.0	59.9
AVERAGE ABSOLUTE VALUE OF DEVIATION:									
0.43	0.35	0.03	0.00	0.03	0.25	0.36	0.34	0.42	0.05

Line# 3 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

APPENDIX P

UNPROCESSED AND AVERAGED DATA: 1979

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RUN NUMBER 12 DATA SET # 73 STARTING FILE# 267
STORED IN FILE # 70

P1	Mf(mv)	Tf	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
193.4	47.4	407.0	0.0	393.7	33.5	518.0	487.4	596.6	60.1	204.0	10.1
185.9	41.2	407.1	0.0	393.2	36.3	516.8	488.3	595.9	60.0	204.0	14.1
185.0	47.6	407.1	0.0	393.2	36.9	517.4	488.6	596.6	60.1	204.0	11.8
188.7	45.2	407.1	0.0	393.0	35.8	518.0	487.4	595.1	60.0	204.0	14.5
189.7	45.3	406.9	0.0	392.5	35.8	517.4	486.8	595.1	60.1	204.0	12.3

AVERAGE VALUE:

188.5	45.3	407.0	0.0	393.1	35.7	517.5	487.7	595.9	60.1	204.0	12.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

2.46	1.72	0.09	0.00	0.29	0.85	0.38	0.60	0.60	0.05	0.0	1.4

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 12 DATA SET # 74 STARTING FILE# 273
STORED IN FILE # 72

P1	Mf(av)	Tf	Mv(av)	Tv	T%	kW	volts	amps	freq	T2	P2
115.5	45.7	406.5	0.0	387.8	96.6	513.8	485.0	592.9	60.0	204.0	9.2
111.7	45.7	406.4	0.0	387.8	100.0	506.0	480.8	589.1	59.7	204.0	15.2
112.4	46.6	406.5	0.0	387.6	99.9	510.2	484.1	591.4	59.9	204.0	15.9
112.7	45.0	406.4	0.0	385.8	99.8	510.2	483.5	591.4	60.0	204.0	10.1
115.1	41.7	406.5	0.0	387.6	95.7	510.8	484.4	591.4	60.0	204.0	14.5
AVERAGE VALUE:											
113.5	44.9	406.5	0.0	387.3	98.4	510.2	483.6	591.2	59.9	204.0	13.0
AVERAGE ABSOLUTE VALUE OF DEVIATION:											
1.46	1.28	0.06	0.00	0.59	1.80	1.68	1.13	0.84	0.08	0.0	2.6

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 12 DATA SET # 75 STARTING FILE# 279
STORED IN FILE # 74

P1	Mf(av)	Tf	Mv(av)	Tv	T%	kW	volts	amps	freq	T2	P2
186.9	9.9	394.4	15.8	411.2	29.1	504.8	480.5	586.9	60.0	203.0	10.3
185.7	9.9	394.1	15.8	411.2	29.0	504.8	482.9	587.6	60.1	203.0	11.1
184.7	9.8	394.1	15.7	411.1	29.9	503.6	480.8	587.6	60.2	203.0	11.7
185.7	10.1	393.9	16.0	411.2	29.3	505.4	481.7	588.4	60.2	203.0	13.9
185.6	10.0	393.9	15.6	411.1	28.6	505.4	480.8	587.6	60.0	202.5	11.7

AVERAGE VALUE:

185.7	9.9	394.1	15.8	411.2	29.2	504.8	481.4	587.6	60.1	202.9	11.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.46	0.10	0.16	0.11	0.04	0.32	0.48	0.77	0.30	0.09	0.2	0.9

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 12 DATA SET # 76 STARTING FILE# 4
STORED IN FILE # 75

P1	Mf(mv)	Tf	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
105.3	13.5	393.2	10.3	411.9	99.9	485.6	475.4	572.6	60.0	203.0	12.3
104.3	13.4	393.2	10.3	411.8	100.0	482.0	474.8	570.4	59.9	203.0	12.3
104.0	13.6	393.2	10.5	411.9	100.1	485.6	476.9	572.6	60.0	203.0	12.1
104.9	13.4	393.[illegible]	10.4	412.0	100.2	484.4	473.9	572.6	60.0	203.0	12.1
105.2	13.3	393.2	10.4	411.9	100.0	485.6	476.0	574.1	60.2	203.0	12.2

AVERAGE VALUE:

104.7	13.4	39[illegible]	[illegible].4	411.9	100.1	484.6	475.4	572.5	60.0	203.0	12.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.48	0.10	0.00	0.06	0.06	0.09	1.15	0.84	0.84	0.06	0.0	0.1

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 12 DATA SET # 77 STARTING FILE# 10
STORED IN FILE # 77

P1	Mf(av)	Tf	Mv(av)	Tv	TZ	kW	volts	amps	freq	T2	P2
189.3	168.9	385.5	·	409.6	27.8	506.0	489.2	580.9	60.0	203.0	13.6
190.0	170.0	385.4	28.1	409.7	26.0	509.0	489.2	585.4	60.2	203.0	10.6
187.8	168.5	385.3	27.4	409.7	27.9	506.0	486 8	582.4	60.2	202.5	13.4
189.0	168.7	385.2	27.8	409.6	26.6	507.8	488.0	584.5	60.2	202.5	12.9
189.0	170.4	384.8	28.2	409.4	26.7	509.6	487.7	583.9	60.1	202.5	10.9

AVERAGE VALUE:

189.0	169.3	385.2	27.9	409.6	27.0	507.7	488.2	583.4	60.2	202.7	12.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.49	0.70	0.21	0.23	0.09	0.70	1.34	0.82	1.44	0.	0.2	1.2

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 12 DATA SET # 79 STARTING FILE# 20
STORED IN FILE # 78

P1	Mf(av)	Tf	Mv(av)	Tv	T1	kW	volts	amps	freq	T2	P2
104.0	180.7	383.0	27.2	409.9	100.0	491.0	479.9	574.9	60.1	203.0	13.0
103.1	179.7	382.9	27.4	409.9	100.1	489.8	478.1	574.9	60.0	203.0	13.8
103.7	180.3	382.7	27.3	409.7	100.0	489.8	477.5	574.9	60.0	202.5	11.0
103.4	182.2	382.6	27.2	409.9	100.1	495.8	480.5	577.1	60.2	202.5	11.8
103.7	182.0	382.5	27.2	410.1	100.0	495.8	481.4	577.1	60.1	202.5	11.9

AVERAGE VALUE:

103.6	181.0	382.7	27.3	409.9	100.1	492.4	479.5	575.8	60.1	202.7	12.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.27	0.89	0.17	0.05	0.08	0.05	2.69	1.35	1.08	0.05	0.2	0.9

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 13 DATA SET # 80 STARTING FILE# 25
STORED IN FILE # 79

P1	Mf(mv)	Tf	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
164.6	147.2	375.6	46.0	388.9	71.1	752.6	459.5	915.9	60.2	203.0	12.8
161.5	144.2	375.5	50.8	389.0	71.6	750.8	461.3	915.9	60.3	203.5	12.6
161.8	146.3	375.5	50.6	389.0	71.9	751.4	459.5	915.9	60.2	203.0	13.0
161.2	146.3	375.6	48.9	388.9	72.0	753.2	459.5	915.9	60.2	203.0	12.5
163.7	148.0	375.6	49.4	389.0	71.4	751.4	458.6	914.4	60.2	202.5	12.5

AVERAGE VALUE:

162.6	146.4	375.5	49.1	389.0	71.6	751.9	459.7	915.6	60.2	203.0	12.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.26	0.97	0.04	1.36	0.05	0.29	0.82	0.65	0.48	0.02	0.2	0.2

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 13 DATA SET # 81 STARTING FILE# 31
STORED IN FILE # 81

P1	Mf(av)	Tf	Mv(av)	Tv	T%	kW	volts	amps	freq	T2	P2
148.5	164.9	375.4	59.7	388.1	100.0	782.6	466.7	931.6	60.0	203.0	12.7
149.4	165.8	375.5	52.0	388.1	100.0	784.4	467.9	934.6	60.3	203.5	12.8
148.5	164.5	375.7	53.7	388.1	100.0	785.0	469.1	932.4	59.9	203.0	12.8
149.4	168.2	375.9	53.2	388.1	100.0	785.6	467.9	934.6	60.2	203.5	13.1
151.3	164.1	375.9	51.2	388.1	100.0	783.8	467.9	932.4	59.9	203.0	12.8

AVERAGE VALUE:

149.4	165.5	375.7	53.9	388.1	100.0	784.3	467.9	933.1	60.1	203.2	12.8

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.74	1.18	0.20	2.29	0.02	0.00	0.86	0.48	1.20	0.13	0.2	0.1

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 13 DATA SET # 82 STARTING FILE# 37
STORED IN FILE # 83

P1	Mf(av)	Tf	Mv(av)	Tv	T%	kW	volts	amps	freq	T2	P2
143.9	43.2	393.4	74.1	403.4	100.0	795.2	4[illegible].1	936.9	60.0	202.0	8.7
144.2	43.5	393.1	74.4	403.4	100.1	792.8	474.8	936.1	59.9	202.0	16.3
144.5	44.2	392.8	74.1	403.3	100.0	794.0	474.2	936.9	60.1	202.0	19.3
144.5	43.5	392.5	73.7	403.4	100.0	797.6	475.7	938.4	60.2	202.0	10.4
143.9	44.0	392.3	74.2	403.4	100.0	795.8	[illegible]	937.6	60.0	202.5	11.9

AVERAGE VALUE:

144.2	43.7	392.8	74.1	403.4	100.0	795.1	475.2	937.2	60.0	202.1	13.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.25	0.33	0.34	0.17	0.02	0.03	1.34	0.55	0.66	0.08	0.2	3.6

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 13 DATA SET # 83 STARTING FILE# 42
STORED IN FILE # 84

P1	Mf(mv)	Tf	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
143.9	45.1	391.6	74.2	403.4	79.9	794.6	473.9	935.4	60.0	202.0	18.9
144.5	44.6	391.5	74.3	403.4	100.1	793.4	475.7	936.1	59.8	202.0	10.1
143.9	44.7	391.5	73.9	403.3	100.0	795.2	475.1	937.6	60.0	202.0	9.6
143.9	44.6	391.4	74.1	403.3	100.0	792.8	474.2	936.1	60.0	202.0	15.1
144.2	44.7	391.4	73.8	403.3	100.0	791.6	476.3	933.9	59.9	202.5	16.9
144.5	45.0	391.4	73.6	403.3	100.0	792.8	476.0	936.9	60.0	202.5	9.6
143.7	44.3	391.3	73.7	403.3	100.0	794.0	474.2	937.6	60.1	202.5	11.6
144.2	44.6	391.2	73.6	403.4	100.0	799.4	463.1	945.2	60.2	202.5	13.0
144.8	45.1	391.2	74.8	403.4	100.0	801.2	475.7	941.4	60.2	202.5	18.4
145.1	45.5	391.2	73.5	403.4	100.0	797.0	473.3	939.9	60.0	202.5	16.6

AVERAGE VALUE:

144.3	44.8	391.4	74.0	403.3	100.0	795.2	473.8	938.0	60.0	202.3	14.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.35	0.30	0.10	0.33	0.03	0.02	2.40	2.22	2.48	0.09	0.2	3.2

Line# 1 Col# 6
Line# 2 Col# 6
Line# 8 Col# 8

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

RUN NUMBER 13 DATA SET # 84 STARTING FILE# 53
STORED IN FILE # 95

P1	Mf(mv)	Tf	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
179.4	181.1	399.3	68.3	404.3	100.1	1004.6	477.5	1179.5	60.0	203.0	11.4
180.0	180.7	399.3	64.2	404.4	100.1	999.2	475.1	1178.0	60.1	203.0	10.1
178.2	181.8	399.3	65.2	404.4	100.2	1005.8	478.1	1179.5	60.1	203.0	17.7
178.5	178.3	399.4	65.0	404.4	100.1	1004.0	475.4	1178.7	60.1	203.0	11.8
178.2	174.1	399.3	65.4	404.4	100.0	1004.6	475.1	1178.7	60.2	203.0	14.0
177.9	174.7	399.3	66.8	404.4	100.0	1000.4	476.9	1178.0	60.1	203.0	14.0
180.1	176.5	399.3	66.1	404.3	100.0	1001.6	475.4	1178.0	60.1	203.0	14.2
180.4	175.7	399.3	64.5	404.4	100.0	998.6	474.5	1176.5	60.2	203.5	10.4
181.0	171.5	399.3	68.5	404.4	100.0	998.6	475.1	1178.7	60.2	203.0	13.3
179.7	175.0	399.4	65.0	404.3	100.2	1001.0	476.0	1179.5	60.1	202.5	11.8

AVERAGE VALUE:

179.3	177.0	399.3	65.9	404.3	100.1	1001.8	475.9	1178.5	60.1	203.0	12.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.91	2.82	0.02	1.23	0.03	0.07	2.33	0.97	0.72	0.04	0.1	1.8

Line# 1 Col# 10

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

APPENDIX Q

UNPROCESSED AND AVERAGED DATA: 1980

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RUN NUMBER 0 DATA SET # 34 STARTING FILE# 53
STORED IN FILE # 14

Pi	Mf(mv)	Ti	Mv(mv)	Tv	T7	kW	volts	amps	freq	T2	P2
101.8	2.8	327.3	8.5	0.0	73.6	384.3	488.0	442.1	60.3	213.8	15.0
100.9	2.6	328.1	8.5	0.0	73.7	383.7	487.7	442.1	60.2	213.3	15.0
99.4	2.7	328.5	8.0	0.0	72.0	383.7	489.2	442.9	60.3	213.8	14.9
104.6	2.8	328.8	8.7	0.0	69.5	383.7	488.0	441.4	60.2	213.3	15.0
99.1	2.8	329.2	7.7	0.0	69.5	[illegible]	489.4	442.9	60.3	213.8	14.9
101.2	2.7	329.4	7.5	0.0	67.2	[illegible]	488.3	441.4	60.1	213.3	14.9
99.7	2.7	329.4	7.3	0.0	70.5	383.7	487.4	441.4	60.2	213.3	14.9
102.1	2.8	329.4	8.2	0.0	71.3	383.1	488.6	440.6	60.2	213.3	15.0
101.2	2.8	329.2	8.3	0.0	76.3	383.7	489.4	442.1	60.1	213.3	15.0
99.1	2.8	328.9	7.4	0.0	78.5	383.7	490.3	441.4	60.1	213.3	14.9

AVERAGE VALUE:

100.9	2.8	328.8	8.0	0.0	72.2	383.7	488.6	441.8	60.2	213.4	15.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.29	0.05	0.53	0.41	0.00	2.67	0.22	0.79	0.60	0.08	0.2	0.0

Line# 1 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 0 DATA SET # 36 STARTING FILE# 64
STORED IN FILE # 16

Pi	Mf(mv)	Ti	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
140.1	2.6	352.9	5.3	0.0	26.2	262.1	471.2	316.1	60.0	213.3	14.8
145.0	2.5	353.7	5.5	0.0	25.7	261.5	471.2	316.9	60.1	212.8	14.9
141.3	2.5	354.1	5.4	0.0	25.6	262.7	471.8	316.9	60.0	213.3	14.9
143.4	2.6	354.3	6.0	0.0	25.4	261.5	473.3	316.9	60.2	213.3	14.9
143.8	2.7	354.5	5.6	0.0	27.6	262.7	471.8	317.6	60.3	212.8	14.8
144.1	2.7	354.6	6.0	0.0	23.7	262.7	471.5	317.6	60.1	213.3	14.9
142.2	2.7	354.7	4.8	0.0	27.2	261.5	473.6	316.1	60.0	212.8	14.8
144.7	2.6	354.6	5.2	0.0	26.6	260.9	470.3	316.1	60.1	213.3	14.7
141.6	2.5	354.7	4.4	0.0	27.5	260.9	471.8	315.4	59.8	212.8	14.7
139.1	2.6	354.7	5.1	0.0	25.0	262.7	471.5	316.9	60.0	213.3	14.[illegible]

AVERAGE VALUE:

142.5	2.6	354.3	5.3	0.0	26.1	261.9	471.8	316.7	60.1	213.1	14.8

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.66	0.05	0.42	0.37	0.00	0.96	0.66	0.66	0.57	0.09	0.2	0.1

Line# 1 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 0 DATA SET # 39 STARTING FILE# 76
STORED IN FILE # 20

P1	Mf(mv)	T1	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
138.8	2.9	354.9	12.0	0.3	50.8	510.7	473.9	612.4	59.8	213.8	15.2
140.7	2.9	354.4	10.4	0.0	47.6	513.7	472.4	616.9	59.9	213.8	15.0
141.3	2.7	354.3	11.7	0.0	46.6	513.7	474.8	613.9	60.0	213.8	15.[illegible]
139.1	2.7	354.2	10.8	0.0	48.5	513.7	472.4	613.9	59.9	213.8	15.0
140.1	2.8	353.9	10.4	0.0	49.9	513.1	474.8	613.9	59.8	213.8	15.1
139.7	2.9	353.8	10.6	0.0	47.7	513.7	472.4	614.6	59.9	213.8	15.1
139.4	2.9	353.7	11.5	0.0	48.7	513.7	473.0	614.6	59.9	213.8	15.2
141.3	2.9	353.8	11.4	0.0	49.2	511.9	474.2	613.9	59.9	213.8	15.2
141.3	2.9	353.7	10.5	0.0	49.1	512.5	472.4	613.9	59.9	213.8	15.1
136.7	2.8	353.6	12.0	0.0	50.8	513.1	474.8	613.9	59.9	213.8	15.2

AVERAGE VALUE:

139.8	2.8	354.0	11.2	0.0	48.9	513.0	473.5	614.2	59.9	213.8	15.1

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.08	0.05	0.33	0.57	0.00	1.07	0.77	0.99	0.72	0.04	0.0	0.1

Line# 2 Col# 9

Number of data sets for which the deviation
exceeds 3X the average deviation. 1

RUN NUMBER 0 DATA SET # 42 STARTING FILE# 88
STORED IN FILE # 23

P1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
177.4	2.7	373.7	10.7	0.0	30.1	[illegible]1.9	472.4	613.1	59.9	213.8	15.1
179.8	3.0	373.7	9.6	0.0	32.1	513.7	474.8	613.9	60.1	213.3	15.0
180.8	2.9	373.7	10.7	0.0	32.3	511.9	471.8	613.9	60.2	213.8	15.1
182.3	2.8	373.7	10.2	0.0	31.1	513.1	473.0	615.4	60.2	213.8	15.1
177.7	2.8	373.8	11.4	0.0	29.5	515.5	473.3	616.1	60.3	213.8	15.1
183.2	2.8	373.7	12.2	0.0	32.0	514.3	474.5	615.4	60.3	213.8	15.3
179.2	2.8	373.6	12.0	0.0	32.6	513.7	474.8	614.6	60.1	213.8	15.3
182.3	2.7	373.7	12.0	0.0	32.4	511.9	472.7	615.4	60.3	213.8	15.2
180.5	2.6	373.6	11.1	0.0	30.2	513.1	473.0	615.4	60.2	213.8	15.3
178.0	2.7	373.5	10.5	0.0	31.0	515.5	473.3	615.4	60.2	213.8	15.1

AVERAGE VALUE:

180.1	2.8	373.7	11.0	0.0	31.3	513.5	473.3	614.8	60.2	213.7	15.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.70	0.10	0.08	0.70	0.00	0.92	1.08	0.80	0.78	0.08	0.1	0.1

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 73 STARTING FILE# 7
STORED IN FILE # 4

P1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
142.8	2.7	354.1	17.4	0.0	68.9	649.1	494.8	744.4	60.0	214.3	15.4
145.6	2.7	354.5	17.4	0.0	67.4	650.3	494.8	745.9	60.4	214.3	15.2
140.3	2.7	354.9	17.6	0.0	68.8	649.7	495.4	744.4	60.1	214.3	15.4
143.1	2.7	355.1	17.5	0.0	66.2	647.9	495.4	742.9	60.1	214.8	15.2
142.5	2.7	355.2	17.3	0.0	68.8	648.5	495.7	742.9	60.2	214.8	15.4

AVERAGE VALUE:

142.9	2.7	354.7	17.5	0.0	68.0	649.1	495.3	744.1	60.2	214.5	15.3

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.18	0.01	0.36	0.07	0.00	1.00	0.72	0.34	0.96	0.10	0.2	0.1

Number of data sets for which the dev' tion
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 78 STARTING FILE# 16
STORED IN FILE # 9

P1	Mf(mv)	T1	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
175.5	2.8	371.7	27.5	0.0	71.9	858.2	496.3	990.3	60.1	215.8	15.9
173.3	2.9	371.3	28.5	0.0	72.1	857.6	493.6	988.8	60.0	215.8	16.0
172.4	2.9	371.0	27.1	0.0	69.2	856.4	496.0	988.8	59.9	215.8	15.9
173.0	2.8	370.8	28.3	0.0	70.3	856.4	493.3	988.8	60.1	215.8	16.1
174.2	2.8	370.6	28.5	0.0	73.5	855.8	496.0	988.1	60.1	215.8	16.1
175.8	2.8	370.6	27.6	0.0	67.9	857.6	496.3	988.8	60.1	215.8	15.8
177.0	2.8	370.8	28.0	0.0	67.3	856.4	494.2	989.6	60.2	215.8	16.1
176.7	2.8	371.0	28.0	0.0	66.1	857.6	494.2	988.8	60.1	215.8	16.0
178.2	2.8	371.4	26.9	0.0	65.2	857.0	493.9	989.6	60.0	215.8	15.9
177.3	2.8	371.6	27.8	0.0	66.1	856.4	494.5	988.8	60.2	215.8	16.0

AVERAGE VALUE:

175.3	2.8	371.1	27.8	0.0	69.0	856.9	494.9	989.1	60.1	215.8	16.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.69	0.03	0.33	0.43	0.00	2.44	0.66	1.06	0.46	0.07	0.0	0.1

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 84 STARTING FILE# 37
STORED IN FILE # 15

P1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
96.3	2.1	326.0	8.3	0.0	74.1	219.0	487.7	254.6	60.2	239.6	25.2
93.8	2.1	325.5	7.4	0.0	76.0	219.6	486.5	253.9	60.2	239.	24.7
95.6	2.1	325.5	8.4	0.0	76.9	219.0	489.3	253.9	60.5	239.6	25.0
96.2	2.1	325.5	8.2	0.0	72.9	219.0	486.5	253.9	60.6	239.6	24.6
94.7	2.1	325.4	8.6	0.0	67.7	219.0	487.4	254.6	60.7	239.6	23.8
96.8	2.1	325.4	7.8	0.0	67.5	219.6	485.6	253.1	60.5	239.6	24.0
101.2	2.1	325.9	8.7	0.0	67.8	219.0	486.6	253.1	60.4	239.0	24.8
95.3	2.1	326.6	8.5	0.0	68.0	219.6	485.6	253.9	60.6	239.6	25.3
102.1	2.1	327.3	8.4	0.0	68.1	219.6	486.5	254.6	60.8	240.1	25.8
99.3	2.1	327.7	8.2	0.0	66.4	219.0	486.8	253.9	60.6	240.1	24.7

AVERAGE VALUE:

97.5	2.1	326.1	8.2	0.0	70.6	219.2	486.7	254.0	60.5	239.6	24.8

AVERAGE ABSOLUTE VALUE OF DEVIATION:

2.35	0.02	0.68	0.28	0.00	3.54	0.29	0.63	0.40	0.16	0.2	0.4

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER C DATA SET # 87 STARTING FILE# 49
STORED IN FILE # 18

P1	Mf(av)	T1	Mv(av)	Tv	TZ	kW	volts	amps	freq	T2	P2
147.1	2.3	353.7	16.9	0.0	57.[illegible]	[illegible]4.3	494.5	440.6	60.4	254.6	30.6
144.0	2.3	355.3	17.6	0.0	60.8	383.1	492.7	439.1	60.0	254.1	31.6
138.5	2.3	355.2	16.3	0.0	64.7	383.1	495.7	439.1	59.8	254.6	30.7
132.0	2.2	354.3	16.9	0.0	69.2	384.3	493.6	439.9	59.7	254.1	31.9
132.3	2.3	353.1	16.6	0.0	76.6	383.7	495.7	440.6	59.7	253.6	32.3
135.1	2.3	352.1	19.1	0.0	80.1	384.3	493.6	440.6	59.9	254.1	32.7
137.6	2.3	351.5	17.6	0.0	74.8	383.1	492.7	439.1	60.2	254.6	33.4
139.7	2.3	351.6	18.2	0.0	66.3	383.7	492.7	439.9	60.3	254.6	30.3
140.6	2.3	352.2	18.0	0.0	63.1	383.1	495.7	439.9	60.3	255.1	31.9
145.6	2.2	353.2	17.4	0.0	58.8	384.9	493.9	442.1	60.6	254.6	32.1

AVERAGE VALUE:

139.2	2.3	353.2	17.5	0.0	67.1	383.8	494.1	440.1	60.1	254.4	31.8

AVERAGE ABSOLUTE VALUE OF DEVIATION:

4.16	0.03	1.12	0.63	0.00	6.42	0.55	1.06	0.72	0.27	0.3	0.8

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 90 STARTING FILE# 61
STORED IN FILE # 21

P1	Mf(av)	T1	Mv(av)	Tv	TZ	kW	volts	amps	freq	T2	P2
177.0	2.7	372.2	28.0	0.0	64.8	471.8	485.6	551.6	60.0	267.2	40.9
171.4	2.7	371.5	25.5	0.0	62.0	470.0	483.8	551.6	59.9	266.7	38.9
175.1	2.7	371.4	27.4	0.0	62.9	470.6	484.1	551.6	60.0	266.7	39.9
171.7	2.7	371.2	25.4	0.0	61.6	471.8	485.6	553.1	60.2	266.7	39.0
174.2	2.7	371.0	26.9	0.0	62.0	471.2	484.4	552.4	60.2	266.7	39.6
174.5	2.7	371.2	26.1	0.0	61.6	471.8	484.1	553.1	60.3	266.7	39.2
178.2	2.7	371.3	28.5	0.0	59.9	471.8	485.3	553.1	60.2	266.7	40.0
177.0	2.7	371.5	26.4	0.0	60.1	473.6	484.1	553.1	60.2	266.7	39.6
176.1	2.7	371.8	27.9	0.0	60.5	470.0	483.2	552.4	60.0	266.7	39.5
177.3	2.7	371.9	25.3	0.0	60.4	470.6	483.8	552.4	60.1	266.7	39.2

AVERAGE VALUE:

175.3	2.7	371.5	26.7	0.0	61.6	471.3	484.4	552.4	60.1	266.7	39.6

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.85	0.01	0.29	1.00	0.00	1.10	0.84	0.66	0.54	0.10	0.1	0.4

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 92 STARTING FILE# 72
STORED IN FILE # 23

P1	Mf(mv)	T1	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
14.9	1.9	224.1	0.1	0.0	-0.0	-0.9	-0.4	-1.1	55.0	211.4	14.6
15.5	1.9	224.1	0.0	0.0	-0.3	-0.9	-0.4	-1.1	55.0	211.4	14.5
14.9	1.9	224.1	0.1	0.0	-0.0	-0.9	-0.4	-1.1	55.0	210.9	14.6
15.2	1.9	224.1	0.1	0.0	-0.1	-0.9	-0.4	-1.1	55.0	210.9	14.5
15.2	1.9	224.1	0.1	0.0	-0.0	-0.9	-0.4	-1.1	55.0	210.9	14.5

AVERAGE VALUE:

15.1	1.9	224.1	0.1	0.0	-0.1	-0.9	-0.4	-1.1	55.0	211.1	14.5

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.20	0.02	0.00	0.02	0.00	0.10	0.00	0.05	0.00	0.00	0.2	0.0

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 94 STARTING FILE# 78
STORED IN FILE # 25

P1	Mf(mv)	T1	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
28.2	0.0	248.0	0.2	0.0	97.1	-0.9	2.3	-1.1	55.0	212.9	14.8
31.6	0.0	250.8	0.2	0.0	97.1	-0.9	3.5	-1.1	55.0	212.9	14.9
32.5	0.0	252.5	0.1	0.0	97.1	-0.9	4.4	-1.1	55.0	212.9	14.9

AVERAGE VALUE:

30.8	0.0	250.4	0.1	0.0	97.1	-0.9	3.4	-1.1	55.0	212.9	14.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.71	0.00	1.63	0.04	0.00	0.00	0.00	0.73	0.00	0.00	0.0	0.0

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 96 STARTING FILE# 82
STORED IN FILE # 27

P1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
94.8	2.2	327.6	11.4	0.0	77.9	211.8	485.3	251.6	60.2	240.1	24.8
94.5	2.2	326.2	11.7	0.0	80.1	211.8	485.0	251.6	60.3	240.1	24.7
97.6	2.2	326.0	11.8	0.0	78.5	211.2	483.2	252.4	60.6	240.6	25.0
98.5	2.3	326.3	11.4	0.0	73.9	211.2	483.2	251.6	60.5	240.6	24.4
101.0	2.3	326.7	11.0	0.0	71.7	211.2	483.2	252.4	60.6	240.6	25.0
99.1	2.3	327.4	11.4	0.0	69.2	211.8	482.9	250.9	60.4	240.1	24.7
102.8	2.3	328.0	11.6	0.0	69.6	211.8	483.8	252.4	60.4	240.1	24.7
99.4	2.2	328.4	11.1	0.0	71.1	211.2	485.0	252.4	60.5	240.6	24.7
102.2	2.2	328.7	11.8	0.0	70.0	211.8	484.1	251.6	60.5	240.1	24.3
101.0	2.2	329.0	11.8	0.0	69.6	211.2	483.5	251.6	60.4	240.1	24.8

AVERAGE VALUE:

99.1	2.2	327.4	11.5	0.0	73.1	211.5	483.9	251.9	60.4	240.3	24.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

2.19	0.02	0.90	0.25	0.00	3.57	0.30	0.74	0.42	0.09	0.2	0.2

Number of data sets for which the deviation
exceeds 3X the average deviation: 0

RUN NUMBER 0 DATA SET # 99 STARTING FILE# 94
STORED IN FILE # 30

P1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
142.9	2.7	355.0	18.6	0.0	61.8	287.3	505.0	323.6	60.4	255.1	31.8
143.5	2.7	355.2	18.8	0.0	58.3	287.9	502.3	323.6	60.3	254.6	31.6
140.4	2.6	355.3	18.1	0.0	58.9	287.3	504.4	322.9	60.3	254.6	32.0
142.9	2.6	355.4	19.9	0.0	59.6	287.3	502.0	322.1	60.2	254.6	31.4
140.4	2.7	355.4	18.6	0.0	59.8	288.5	505.0	324.4	60.4	254.6	32.5
144.7	2.7	355.4	19.0	0.0	60.5	287.3	502.0	323.6	60.4	254.6	32.7
142.9	2.7	355.4	19.2	0.0	60.9	287.9	502.6	324.4	60.5	254.6	31.6
143.5	2.7	355.4	17.5	0.0	57.3	287.3	501.7	322.9	60.3	254.6	32.1
142.6	2.7	355.4	18.4	0.0	58.3	287.9	504.7	325.1	60.4	254.6	31.3
144.7	2.7	355.4	18.8	0.0	60.2	287.9	501.4	323.6	60.5	254.6	31.4

AVERAGE VALUE:

142.9	2.7	355.3	18.7	0.0	59.6	287.6	503.2	323.6	60.4	254.7	31.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.03	0.01	0.10	0.44	0.00	1.07	0.36	1.33	0.60	0.07	0.1	0.4

Line# 1 Col# 3

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 0 DATA SET # 102 STARTING FILE# 106
STORED IN FILE # 33

P1	Mf(mv)	T1	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
180.8	2.9	372.6	28.7	0.0	57.1	399.3	473.0	481.9	60.3	267.2	39.9
175.3	2.9	372.7	29.3	0.0	60.1	398.7	475.4	484.1	60.3	267.2	40.1
176.5	2.9	372.6	30.5	0.0	58.4	399.3	475.4	482.6	60.3	267.2	40.8
177.7	2.8	372.5	29.6	0.0	58.5	399.9	473.9	482.6	60.2	267.2	39.5
175.3	2.9	372.5	29.6	0.0	60.0	398.7	473.0	481.9	60.2	267.2	39.5
179.0	2.9	372.4	29.6	0.0	58.6	399.9	473.0	481.9	60.3	267.2	39 8
177.4	2.8	372.4	29.4	0.0	60.9	398.7	472.7	482.6	60.3	267.2	40.1
175.3	2.8	372.4	29.8	0.0	59.1	401.1	475.7	483.4	60.2	267.7	41.3
176.2	2.9	372.3	29.6	0.0	59.4	399.9	474.8	481.1	60.2	267.2	38.9
174.6	2.8	372.3	29.3	0.0	59.2	398.1	473.0	482.6	60.2	267.2	39.7

AVERAGE VALUE:

176.8	2.9	372.5	29.5	0.0	59.1	399.4	473.9	482.5	60.2	267.2	39.9

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.54	0.04	0.12	0.30	0.00	0.78	0.67	1.07	0.63	0.04	0.1	0.5

Line# 3 Col# 4

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 0 DATA SET # 104 STARTING FILE# 117
STORED IN FILE # 35

P1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
14.4	-0.1	224.1	0.1	0.0	1.8	-0.9	-0.4	-1.1	55.0	172.2	14.7
14.4	-0.1	224.1	0.1	0.0	1.8	-0.9	-0.4	-1.1	55.0	171.7	14.7
14.4	-0.1	224.1	0.1	0.0	1.5	-0.9	-0.4	-1.1	55.0	171.7	14.7
14.4	-0.1	224.1	0.0	0.0	1.6	-0.9	-0.4	-1.1	55.0	171.7	14.7
14.7	-0.1	224.1	0.0	0.0	1.7	-0.9	-0.4	-1.8	55.0	171.7	14.6
98.7	2.2	327.9	6.3	0 0	56.1	260.4	480.4	306.8	60.3	213.4	15.0

AVERAGE VALUE:

28.5	0.3	241.4	1.1	0.0	10.8	42.7	79.7	50.1	55.9	178.7	14.7

AVERAGE ABSOLUTE VALUE OF DEVIATION:

23.40	0.65	28.84	1.74	0.00	15.12	72.57	133.56	85.56	1.47	11.6	0.1

Line# 6 Col# 4

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 0 DATA SET # 105 STARTING FILE# 123
STORED IN FILE # 35

P1	Mf(mv)	T1	Mv(mv)	Tv	TX	kW	volts	amps	freq	T2	P2
96.4	2.2	326.7	6.1	0.0	59.3	260.3	481.1	306.4	60.1	213.4	15.0
96.8	2.2	327.7	7.0	0.0	55.8	260.3	479.6	307.1	60.5	213.4	15.0
98.2	2.2	328.2	5.8	0.0	53.6	259.7	481.7	307.9	60.2	213.4	15.1
98.5	2.2	328.4	6.2	0.0	55.1	260.3	480.8	305.6	60.2	213.4	15.1
101.0	2.2	328.5	6.9	0.0	54.6	260.3	481.7	306.4	60.4	213.9	15.1
101.6	2.3	328.8	6.6	0.0	53.0	260.3	479.3	305.6	60.4	213.4	14.9
99.8	2.3	329.0	6.4	0.0	55.4	260.3	482.0	306.4	60.4	213.4	14.9
99.5	2.2	329.1	6.4	0.0	51.9	260.3	481.4	307.1	60.3	213.4	15.0
100.1	2.2	328.9	6.4	0.0	55.7	260.3	482.0	307.1	60.3	213.4	14.9
97.6	2.2	328.6	6.1	0.0	54.8	260.3	479.6	304.9	60.3	213.4	15.0

AVERAGE VALUE:

99.2	2.2	328.4	6.4	0.0	54.9	260.2	480.9	306.5	60.3	213.5	15.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.17	0.02	0.51	0.28	0.00	1.32	0.11	0.88	0.69	0.11	0.1	0.0

Line# 1 Col# 3
Line# 3 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 2

RUN NUMBER 0 DATA SET # 109 STARTING FILE# 136
STORED IN FILE # 39

Pi	Mf(mv)	Ti	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
102.5	2.3	329.0	10.7	0.0	81.2	426.2	491.5	496.9	60.5	213.9	15.2
101.9	2.3	329.8	11.0	0.0	76.7	426.8	492.4	497.6	60.6	213.9	15.1
101.3	2.3	330.1	10.0	0.0	75.5	426.8	491.8	498.4	60.6	213.9	15.2
100.4	2.4	330.2	10.0	0.0	78.5	426.2	489.2	497.6	60.6	213.9	15.2
103.8	2.3	330.3	10.8	0.0	77.6	425.6	489.2	497.6	60.7	213.9	15.2
105.6	2.3	330.8	9.4	0.0	71.4	427.4	491.8	498.4	60.6	213.9	15.1
103.4	2.3	331.0	10.1	0.0	74.9	426.2	491.2	498.4	60.6	213.9	15.2
103.5	2.3	331.2	9.9	0.0	73.2	425.0	490.9	497.6	60.6	213.9	15.2
105.0	2.3	331.2	10.7	0.0	76.6	425.0	489.7	497.6	60.6	213.9	15.2
101.6	2.3	331.0	10.2	0.0	79.5	426.8	488.9	496.9	60.5	213.9	15.2

AVERAGE VALUE:

102.9	2.3	330.5	10.3	0.0	76.5	426.2	490.7	497.7	60.6	213.9	15.2

AVERAGE ABSOLUTE VALUE OF DEVIATION:

1.35	0.03	0.58	0.42	0.00	2.21	0.60	1.16	0.40	0.06	0.0	0.0

Line# 4 Col# 2

Number of data sets for which the deviation
exceeds 3X the average deviation: 1

RUN NUMBER 0 DATA SET # 112 STARTING FILE# 148
STORED IN FILE # 42

P1	Mf(mv)	T1	Mv(mv)	Tv	TZ	kW	volts	amps	freq	T2	P2
137.7	2.1	352.7	6.2	0.0	36.0	271.1	488.6	313.9	60.3	213.4	15.1
140.8	2.2	353.0	6.7	0.0	33.2	270.5	486.2	313.9	60.4	213.4	15.0
137.7	2.2	353.0	6.8	0.0	32.5	270.5	487.7	313.9	60.3	213.4	15.0
140.2	2.1	353.0	7.3	0.0	33.4	271.1	487.4	313.9	60.5	213.4	15.0
138.3	2.1	353.1	7.7	0.0	34.9	269.9	485.9	313.9	60.4	213.4	15.1
138.3	2.1	353.1	7.3	0.0	34.9	270.5	485.9	313.1	60.3	213.9	15.0
137.4	2.1	353.0	7.0	0.0	35.0	270.5	488.3	313.9	60.4	213.4	15.0
139.5	2.1	353.0	5.7	0.0	32.9	269.9	486.2	313.1	60.2	213.4	15.0
137.7	2.1	352.9	6.6	0.0	33.8	270.5	489.2	313.9	60.3	213.4	15.0
137.7	2.1	352.9	5.3	0.0	34.7	268.1	485.9	312.4	60.2	213.4	15.0

AVERAGE VALUE:

138.5	2.1	353.0	6.7	0.0	34.1	270.3	487.1	313.6	60.3	213.5	15.0

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.98	0.02	0.08	0.58	0.00	0.99	0.58	1.11	0.42	0.06	0.1	0.0

Line# 1 Col# 3
Line# 4 Col# 10
Line# 10 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 3

RUN NUMBER 0 DATA SET # 115 STARTING FILE# 160
STORED IN FILE # 45

T1	Mf(mv)	T1	Mv(mv)	Tv	T%	kW	volts	amps	freq	T2	P2
138.6	2.3	354.1	14.4	0.0	52.4	501.7	499.6	568.1	60.0	213.9	15.4
138.0	2.3	354.2	13.4	0.0	52.1	503.5	502.0	571.1	60.1	213.9	15.4
139.8	2.4	354.1	14.0	0.0	52.0	504.7	500.5	570.4	60.1	214.4	15.2
140.2	2.4	354.1	12.7	0.0	51.4	504.1	500.5	569.6	59.9	213.9	15.3
139.5	2.3	354.1	13.2	0.0	52.4	505.3	503.8	571.1	60.0	214.4	15.4
138.0	2.3	354.1	13.4	0.0	49.5	505.3	502.3	571.1	60.1	214.4	15.5
138.6	2.3	354.1	14.2	0.0	51.0	504.1	500.2	568.9	60.0	214.4	15.3
138.9	2.4	354.0	13.0	0.0	50.9	505.3	501.7	570.4	59.9	214.4	15.3
138.0	2.3	354.0	14.4	0.0	50.4	504.7	502.9	570.4	60.1	214.4	15.3
139.2	2.3	354.1	13.2	0.0	53.7	504.1	500.2	569.6	60.1	213.9	15.5

AVERAGE VALUE:

138.9	2.3	354.1	13.6	0.0	51.6	504.3	501.4	570.1	60.0	214.2	15.4

AVERAGE ABSOLUTE VALUE OF DEVIATION:

0.65	0.03	0.05	0.52	0.00	0.95	0.78	1.17	0.81	0.06	0.2	0.1

Line# 1 Col# 7

Number of data sets for which the deviation
exceeds 3X the average deviation: 1